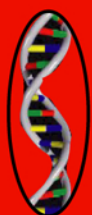




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Handbook of Dental Care

Diagnostic,
Preventive and
Restorative Services

DropBooks

Jose C. Taggart
Editor

Health Care Issues, Costs and Access Series

NOVA

Health Care Issues, Costs and Access Series

HANDBOOK OF DENTAL CARE: DIAGNOSTIC, PREVENTIVE AND RESTORATIVE SERVICES

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Health Care Issues, Costs and Access Series

**HANDBOOK OF DENTAL CARE:
DIAGNOSTIC, PREVENTIVE AND
RESTORATIVE SERVICES**

JOSE C. TAGGART
EDITOR

Nova Biomedical Books
New York

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Contents

Preface		vii
Chapter 1	Psychological Perspectives on Oral Health Behaviours <i>A. L. Dumitrescu, L. Zetu and Silvia Teslaru</i>	1
Chapter 2	The Oral Preventive and Care Measures for Head and Neck Cancer <i>Sirikarn Sutthavong and Pornchai Jansisyanont</i>	35
Chapter 3	Advances in Paediatric Restorative Dentistry <i>Giuseppe Pizzo, Daniela Lo Re, Ignazio Pizzo and Giovanna Giuliana</i>	91
Chapter 4	Evidence-Based Decision Making - Implications for Dental Care <i>Francesco Chiappelli, Olivia S. Cajulis, Oluwadayo Oluwadara and Manisha Harish Ramchandani</i>	117
Chapter 5	Traumatic Dental Injuries: Preventive and Public Health Approaches <i>Giuseppe Pizzo, Maria E. Licata and Giovanna Giuliana</i>	147
Chapter 6	Professional Exposure to Infectious Pathogens in the Dental and Stomatological Environment <i>Roberto Manfredi</i>	163
Chapter 7	Cross Infection Risk in Dental Practice: Evaluation of Environmental Contamination and Personnel Knowledge and Behavior in Italian Public Dental Practices <i>Giorgio Liguori, Christian Napoli, Paolo Castiglia, Francesca Gallé, Maria Teresa Montagna, Cesira Pasquarella and SItI Working Group "Hygiene in Dentistry"</i>	183

Chapter 8	Treating Children with Cleft Lip and Palate: Special Needs and Attention Required During Dental Care <i>Gisele da Silva Dalben, Beatriz Costa, Cleide Felício de Carvalho Carrara, Lucimara Teixeira das Neves and Marcia Ribeiro Gomide</i>	199
Chapter 9	The Use of Artificial Intelligence for Diagnosis and Treatment Planning in Orofacial Disharmonies <i>Hassan Noroozi and Mani Hamzian</i>	267
Chapter 10	Down Syndrome: Need for Jaw Stabilization to Prevent Dysphagia <i>Marie-Noëlle Mazille, Emmanuel Nicolas, Jean-Luc Veyrune, Valérie Roger-Leroi and Martine Hennequin</i>	281
Chapter 11	Computer-Aided Oral Implant Surgery <i>Gerlig Widmann</i>	295
Chapter 12	A Computer-Aided Oral Implantology System in the Placement of Zygoma Implants for Maxillary Reconstruction <i>Chen Xiaojun</i>	333
Chapter 13	Considerations in Dental Care in Implant-Treated Patients <i>Jun-Beom Park</i>	347
Chapter 14	Principal Mycoses of the Oral Cavity <i>M. T. Montagna, R. Iatta, C. Napoli, F. Gallè and G. Liguori</i>	357
Chapter 15	Prevention of Aspiration Pneumonia in the Elderly by Reducing Oropharyngeal Microflora <i>Akira Ishikawa, Yoichiro Miyake, Takeyoshi Yoneyama and Kokichi Miyatake</i>	371
Chapter 16	Patient Autonomy and the Doctor-Patient Relationship in Dentistry: A Review of Research <i>Stephen M. Auerbach</i>	387
Short Communication		
A	The Importance of Pre-Extraction Radiographs <i>L. M. Sykes and R. F. Tadi</i>	401
B	A Simple Method to Ensure Sufficient Occlusal Reduction in Fixed Prosthodontics <i>L. M. Sykes and T. C. N. Buleni</i>	407
Index		413

Preface

This book focuses on new research in dentistry practices. Dentistry is the known evaluation, diagnosis, prevention, and treatment of diseases, disorders and conditions of the oral cavity, maxillofacial area and the adjacent and associated structures and their impact on the human body. Dentistry is widely considered necessary for complete oral health. It usually encompasses a number of very important practices related to the oral cavity. The most common being dental surgery on the teeth as a treatment for dental cavities. Oral and maxillofacial surgery is also a common surgery to correct a wide spectrum of diseases, injuries and defects in the head, neck, face, jaws and the hard and soft tissues of the oral and maxillofacial region. Many oral diseases and abnormalities can indicate systemic, neural, or other diseases. Research on these and other issues related to dental care are discussed in this new book.

Chapter 1 - Psychological science has new opportunities to have major input into the understanding of oral health behaviour. This article provides an overview of advances in understanding the personality characteristics that predispose the development of certain patterns of behaviour: type A behavior pattern, perceived stress, emotional intelligence, aggression, impulsivity, sensation seeking, instability of self-esteem, affective lability, social inhibition, mood, worry, positive and negative affect, social desirability, social intelligence, self-consciousness, anger, self-control, self-confidence, self-competence, self-liking, body investment, body appreciation, perfectionism, sense of hopelessness, worry, type C coping, resilience, hope, self-criticism, narcissism, achievement motives, satisfaction with life and happiness, hardiness, self-concept, self-regulation, proactive coping and attitude, social physique anxiety, shyness, sociability and social comparison. It suggests that it is now time to develop conceptual models that integrate our understanding of separate psychosocial predictors, to explain what oral health behaviour is initiated and how it is maintained or changed.

Chapter 2 - Oral assessment and care are essential prior to cancer treatments in order to decrease both incidence and severity of oral complications. Appropriate interventions have to be performed before the beginning of cancer treatments and/or during the treatment period. It is necessary to regularly perform the oral preventive and care measures by including appropriate counseling to the patients, so they are able to take care of themselves up to the

desired outcome as well as the periodically follow up after the treatments of cancer. This review focuses on the oral preventive and care measures for head and neck cancers.

Chapter 3 - Dental caries has been a highly prevalent and costly disease in the world, representing the most common infectious disease in the paediatric population. Caries lesions are also increasingly isolated in specific teeth and tooth morphology types, and there is growing controversy about the most appropriate restorative material for these lesions in deciduous teeth. In fact, restorative materials continuously improved in durability, strength, aesthetics, and anti-cariogenic properties. Moreover, the increasing demand for aesthetic restorative treatment has totally transformed the practice of paediatric dentistry in the last decade. Traditionally, the use of amalgam was a standard procedure in the restoration of carious primary teeth. Because of the introduction of adhesive restorative materials, the treatment of proximal caries has changed. The principal advantage of these new materials is that they require less retention form and this is particularly important in primary teeth to conserve the relatively thin enamel that could help prevent subsequent carious invasion of dentin.

When planning dental treatment for paediatric patients, each subject and restorative material to be used should be evaluated on an individual basis, in order to provide appropriate care within each material's limitations. This chapter reviews the evolution of restorative materials used in paediatric dentistry, from the amalgam to bonding materials. The current trends and future directions in material research are also discussed. The chemical composition and the physico-chemical properties of the following materials are reported: Amalgam; Stainless steel crown restorations; Pit and fissure sealants; Dentin/enamel adhesives (from the first to the seventh generation); Glass-ionomer cements; Resin-based composites; Compomers. In order to assist the practitioner in the restorative dental care of children and adolescents, the clinical use and the cost-effectiveness of the various materials currently used in paediatric restorative dentistry are also discussed, with a special focus on the dentin/enamel adhesives.

Chapter 4 - Restorative and prosthodontic dental care refer respectively to fixing or to replacing teeth. Whether the dentist intervenes to fill cavities, produce crown or fixed bridges, or engages in the extraction of the affected dental structures and the replacement with some kind of prosthetic device, such as dentures or implants, was largely dependent, until recently in the traditional model of dental care, on sound diagnostic principles, expressed patient needs and wants, and the dentist's expertise. The novel model of dental care that has become increasingly established in the first few years of this new Century is one that strives to complement the former model by a strong reliance on the consensus obtained from all of the best available evidence. By being grounded on systematic reviews and meta-analyses of the entire body of evidence for any clinical case encountered, dental care now evolves and establishes itself as an evidence-based clinical science *par excellence*.

This chapter reviews and discusses the fundamental elements of evidence-based decision-making in dental care. It contrasts the implications and applications of evidence-based dental care for restorative and prosthodontic services, by presenting specific clinical examples for special target populations (e.g., tooth decay in the elderly). It concludes with a set of practical suggestions for dentists seeking to be at *à l'avant garde* of this movement,

and establish their practice as providing sustainable clinical solutions in the context evidence-based decision-making in dental care.

Chapter 5 - Dental trauma can involve injuries to hard tissues and pulp, to periodontal tissues, to bone tissue, and to gingiva and oral mucosa. The aetiology of dental injuries is multi-factorial as they are caused by a complex array of individual clinical factors and social/environmental determinants. Traumatic dental injuries are mainly sustained during sports, through accidents and as a direct result of violence. The prevalence of traumatic dental injuries is not high but there is evidence that the incidence in children's teeth is increasing.

Primary prevention of traumatic dental injuries addresses the control of preventable risk factors through the early treatment of large overjet, the provision of safe playground surfaces and mouth protection in sports. Secondary prevention includes prompt, accurate diagnosis and appropriate initial management in order to improve the prognosis of traumatic dental injuries.

Available evidence indicates that traumatic dental injury is a significant public health problem. Therefore, a treatment approach is unlikely to be successful unless a complementary public health strategy is adopted. Effective public health action should provide high quality clinical care with staff specialized in traumatic dental injuries treatment. Healthy public policies should provide a legislative framework for environmental change in playground layout and for the promotion of mouthguard use in high-risk sports. Health education should be expanded in schools and sport organizations in order to promote the use of mouthguards and improve first-aid treatment by lay people.

Chapter 6 - A review of the main infectious pathogens potentially transmissible to health care professionals during Dentistry and Odonto-Stomatological procedures is carried out, with particular attention focused on parenteral exposure in the dental, stomatological, and surgical environment. Epidemiological issues and specific risk factors are treated systematically on the ground of the available literature sources, together with all available, recommended chemoprophylactic and immunological prophylactic strategies, as updated by the updated knowledge in this field.

Chapter 7 - Infection hazard linked to dental practice is not a recent problem. Some studies have shown that the environment and personnel procedures play an important role in this context. The Working Group "Hygiene in Dentistry" of the Italian Society of Hygiene, Preventive Medicine and Public Health (SItI) deals with infection prevention in dental practice. One of its aims is to evaluate hygienic conditions and risk awareness in public dental services. A study of knowledge of cross-infection hazards and behavior in dental personnel was carried out by questionnaire in some Italian cities. It showed that dental personnel do not follow completely the main procedures for infection control. Environmental microbial contamination in some Italian dental clinics was evaluated. The results showed some critical points in the contamination of water, air and surfaces of the dental surgeries studied. In conclusion, some aspects of daily dental practice may represent a concern for cross infection; therefore, it seems to be absolutely necessary to promote training programs for personnel on the correct use of control procedures in work environments, as well as to draw up a good practical guide for the management of dental outpatient departments.

Chapter 8 - Cleft lip and palate are relatively common congenital malformations. Individuals with this anomaly present characteristic growth and development of the face and stomatognathic system and have some special needs as to the dental care. However, when properly informed and trained, any dental practitioner may deliver high-quality dental care to these patients. Several studies around the world have demonstrated higher caries prevalence among children and adults with cleft lip and palate compared to individuals without clefts. With regard to the children, several factors may contribute for the increased caries risk, including the irregular positioning of teeth; presence of lip fibrosis, which impairs the access for toothbrushing; and the dietary needs of infants, which are breastfed less frequently and for shorter periods, thus having earlier contact with sugar and acidic juices in the baby bottle. In addition to these aspects, many parents may be overindulgent and allow them to eat candies more frequently as an attempt to compensate for the presence of the cleft. The anterior region presents a shallow and fibrotic buccal sulcus, which may complicate the injection of local anesthesia. Thus, topical anesthetic should be applied before the injection, followed by slow and careful injection on the buccal region. The papilla may be penetrated with the anesthetic needle for achievement of initial anesthesia of the palatal region before direct injection in the palate, to avoid pain and discomfort. Also, when treating teeth at the cleft area, it may be necessary to anesthetize both segments anterior and posterior to the alveolar cleft, because these regions present independent innervation due to the presence of the cleft. Tooth extraction and restorative procedures may be performed as usual. In patients with unoperated cleft palate, care is required to avoid aspiration of fragments of teeth and restorative material. Whenever possible, the rubber dam should be used as a protective measure. Knowledge on these different aspects allows dental professionals to provide adequate dental care to these patients, providing favorable conditions to enhance their oral hygiene, esthetics and function and giving an important collaboration for their full rehabilitation.

Chapter 9 - Recognition of orofacial disharmonies and offering appropriate treatment plans according to their signs and symptoms are intelligent actions which are normally performed by a dentist. Using their knowledge and analyzing power, dentists distinguish the signs of the underlying diseases. Can we help dentist in diagnosis and treatment planning using a computerized algorithm? That is the question we are trying to address using intelligent agents. Basically, an intelligent agent is a component that has its own knowledge and owns enough intelligence to analyze it. Using object oriented theory in the computer science, we can model any intelligent agent in an object that has its own "properties and methods". We are trying to find a solution model using the necessary knowledge in the form of "properties of an object". On the other hand, by means of artificial intelligence algorithms, we will make the methods of mentioned object to form "intelligent behavior" for it. The result would be an intelligent agent that takes its required data from different sources like patient, processed images or the dentist. Based on gathered data, the intelligent agent processes the information internally to deliver its findings either as a diagnosis or treatment plan; or as a clue for dentist to do more investigations.

Chapter 10 - Swallowing is a complex, highly-coordinated activity. In the presence of neurodegenerative pathologies, inability to perform safe swallowing can lead to pulmonary infection by aspiration of respiratory pathogens. The risk is decreased by regular oral hygiene and rehabilitation of jaw stabilization, which improves the first step of swallowing.

Mandibular stability is achieved by providing maximum congruency of articulating joint surfaces, ie optimized type and number of dental inter-arch contact units (ICUs) at the end of the jaw closing movement. Many anatomic, congenital, developmental or acquired conditions weaken the stable support base provided by the ICU joint surface and so prevent mandible bone stability. Lack of stability can be caused by tooth loss, often present in elderly persons, and by massive oro-facial dysmorphology such in Down Syndrome. Here we argue for the need to maintain or rehabilitate dental occlusion in Down Syndrome subjects to facilitate the prevention of aspiration pneumonia.

Chapter 11 - In recent years, computer-aided oral implant surgery has been successfully implemented in routine clinical work. It integrates computed tomographic imaging, computerized implant planning and surgical guidance technology. Compared to conventional imaging, multi-slice computed tomography (MSCT) and recent cone-beam computed tomography (CBCT) allow for volumetric evaluation of the boney architecture. Curved multiplanary reconstructions (CMR), panoramic reconstructions (PR), and 3D volume rendering models (VR) are provided. Bone quality can be estimated based on measurement of Hounsfield Units (HU). For prosthetic-driven implant placement, individualized radiographic scan-templates are used. Oral implants are virtually planned on the computer with respect to anatomical and prosthodontic considerations. Compared to standard free hand drilling, surgical navigation systems are used for active instrument tracking based on the presurgical plan. Passive guidance systems use surgical templates manufactured via computer linked mechanical positioners or rapid prototyping. With both approaches successful standard open flap implant surgery, as well as minimal-invasive, transgingival (flapless) surgery, application of early / immediate loading concepts and positioning of zygoma implants have been published.

The present article reviews presurgical imaging, radiographic scan templates, computerized implant planning, different active and passive guidance technology, aspects of accuracy, clinical results, problems and future perspectives of computer-aided oral implant surgery.

Chapter 12 - During the past decades, rehabilitation of maxillary defects still poses a significant challenge for both surgeons and prosthodontists. The advent of zygoma implants presents a unique alternative for maxillary reconstruction without the need for grafting, allows for secure, esthetic, and functional replacement of ablated hard and soft tissues, while minimizing prosthetic complications. However, the placement of zygoma implants is not without risk due to the anatomically complex operation sites and the implant length. In this study, an image guided oral implantology system (IGOIS) is presented to enhance the safety of patients by reducing the risk of damage to adjacent anatomical structures. On the basis of the preoperative data of the CT-scanned patient, surgical planning is accomplished, including 2D/3D geometrical measurements, bone density analysis, bone volume measurement for maxillary defects, optimization design of the position and orientation of oral implants, etc. With the support of an optical tracking device, real-time navigation is achieved through a point-based registration method so that all the preoperative determined implant sites can be drilled carefully according to the original plan under the guidance of 2D/3D interactive image rendering environment. In the following clinical report, IGOIS was successfully used in the treatment for a patient who underwent maxillary resection due to oncology. After the

placement of a total of 4 zygoma implants, the patient was CT-scanned, and then the postoperative images were aligned with the initial planning ones through an automatic image registration method. The result shows that the average distance deviations at the coronal and apical point of the zygoma implant are 1.28 mm (range: 0.8 to 1.8) and 1.68 mm (range: 1.4 to 1.9), and the average angle deviation is 4.10° (range 2.5° to 5.8°), therefore, demonstrates that IGOIS is an accurate method for transferring the planning of a complex osteotomy to the actual surgical procedure.

Chapter 13 - Peri-implant pathology consists of an inflammatory process affecting the soft and hard tissues surrounding the implant, resulting in rapid loss of supporting bone associated with bleeding and suppuration. Mechanical therapy has been proven to affect bacterial infections and it has been suggested as a treatment modality around implants. Chemotherapeutic treatments are also considered essential in eliminating pathogenic organisms from the affected areas. In this view, the treatment of peri-implant mucositis comprises mechanical therapy, subgingival delivery of antiseptic agents, local application of antibiotics or the cumulative combination of above-mentioned treatments.

During the surgery, preoperative antibiotics may be considered to reduce the infectious complications. Applying antiseptic agent such as chlorhexidine before and after implant surgery may be beneficial. Exposed coverscrew may be removed to achieve better hygiene. Additional surgery such as bone graft or soft tissue graft may be needed to achieve better outcomes.

In this review, considerations in implant treatment before, during and after surgery will be reviewed. Various methods to control the peri-implant pathology will be discussed and the effect and efficacy of mechanical and chemotherapeutic treatment will be addressed.

Chapter 14 - Stomatological fungal infections feature various different aetiologies, pathogenesis and clinical presentations. The incidence of these infections is on the increase due to the higher numbers both of patients fitted with dental prostheses and orthodontic braces, and of patients suffering from diseases causing impairment of the immune system.

Oral mycoses can be primary infections (candidiasis, trichosporonosis and rarely zygomycoses) or secondary to systemic infections, such as dimorphic fungi (*Histoplasma*, *Blastomyces*, *Coccidioides*, *Sporothrix*).

Candidiasis is the most common mouth fungal infection. It has been demonstrated that *Candida albicans* is able to adhere strongly to the oral mucosa, in particular in diabetic and HIV patients and in subjects wearing dental braces. These mycoses can produce acute, chronic and mucocutaneous oral lesions in the hosts. Acute pseudomembranous candidiasis, better known as *thrush*, is the most frequent stomatitis due to *C.albicans*.

Non candidal oral infections can be caused by *Cryptococcus* spp or filamentous fungi (*Aspergillus* spp and zygomycetes), that are rarely primary pathogens for the mouth, the oral localization being more commonly secondary to a more serious, systemic infection.

The diagnosis of oral mycoses is mostly based on clinical examination, but microbiological analysis is necessary to identify the aetiological agents and thus institute opportune antifungal therapy. Many methods are now available for performing laboratory analyses, based on different principles, times and costs. Some recent reports have focused on comparisons of the principal characteristics of the more commonly available current laboratory diagnostic systems.

Chapter 15 - Aspiration pneumonia is one of the major causes of a lower QOL for the elderly, and also one of the major causes of elderly people's death. Prevention of aspiration pneumonia is, hence, necessary to maintain the QOL of the elderly. For prevention of aspiration pneumonia, countermeasures should be considered against each risk factor, such as aspiration, poor oral hygiene status, and decreased immunity. Yoneyama et al. reported that continuous oral health care could reduce the incidence of aspiration pneumonia in elderly people. To elucidate the role of oral health care in the prevention of aspiration pneumonia, Ishikawa et al. studied the change in pharyngeal bacterial flora by oral health care using three facilities for the elderly. The changes in pharyngeal total bacteria, *Streptococcus*, *Staphylococcus*, *Candida*, *Pseudomonas* and black-pigmented *Bacteroides* after intervention of professional cleaning of the oral cavity were observed for a 5-month period. These pharyngeal bacteria decreased or disappeared after performing the professional oral health care, i.e., cleaning of teeth, dentures, tongue, and oral mucous membrane by dental hygienists, once a week in each facility. The result suggests that weekly professional oral health care can prevent aspiration pneumonia in the dependent elderly through reducing pharyngeal flora. Oral care is also applied for perioperative patients to prevent respiratory infection after operation or for those in intensive care units.

Chapter 16 - It is widely recognized in medicine that how physicians and patients communicate with each other can have a strong impact on patients' adjustment and response to treatment. Good communication and informed decision making likely promote better health outcomes and are regarded as intrinsic components of good quality care. [1,2] The present paper summarizes the present status of research on the physician-patient relationship and then examines available findings on patient-doctor interactions in dental settings.

Short Communication - Tooth extractions are considered routine procedures in many dental practices. As such, clinicians may become complacent when performing them, especially when patients arrive as emergencies in the middle of a busy day. However, caution, care and good pre-extraction records are advised for every case, as complications may arise when least expected.

Short Communication - When preparing a tooth for a full coverage restoration (overlay, cast metal crown, porcelain jacket crown or porcelain-fused-to-metal crown) it is crucial to ensure that there is adequate occlusal reduction to accommodate the restorative material of choice.

Chapter 1

Psychological Perspectives on Oral Health Behaviours

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Abstract

Psychological science has new opportunities to have major input into the understanding of oral health behaviour. This article provides an overview of advances in understanding the personality characteristics that predispose the development of certain patterns of behaviour: type A behavior pattern, perceived stress, emotional intelligence, aggression, impulsivity, sensation seeking, instability of self-esteem, affective lability, social inhibition, mood, worry, positive and negative affect, social desirability, social intelligence, self-consciousness, anger, self-control, self-confidence, self-competence, self-liking, body investment, body appreciation, perfectionism, sense of hopelessness, worry, type C coping, resilience, hope, self-criticism, narcissism, achievement motives, satisfaction with life and happiness, hardiness, self-concept, self-regulation, proactive coping and attitude, social physique anxiety, shyness, sociability and social comparison. It suggests that it is now time to develop conceptual models that integrate our understanding of separate psychosocial predictors, to explain what oral health behaviour is initiated and how it is maintained or changed.

1. Introduction

Health promotion is a global issue that has drawn much attention from health professionals and the public. Health promotion has been regarded as an effective strategy to improve the nation's health and to attain a high level of well-being for individuals. Not only

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does health promotion decrease disease, it also has been viewed as a mechanism to enhance the well-being of a person or community, beyond that which can be attained by traditional curative medical intervention (Sohng et al., 2002).

There is also a maturing body of research describing psychosocial risk factors for major sources of morbidity and mortality beyond the traditional behavioral risks such as smoking, diet, and activity levels. These increasingly well-established psychosocial risk factors include social isolation, socioeconomic status (SES), personality characteristics, and negative emotions and a growing body of research supports models that identify psychophysiological effects of stress and emotion as the general mechanism underlying their association with disease (Smith et al., 2004).

According to the hypothesis that guides the first line of research, some personality variables predispose individuals to behaviours that could be dangerous to their health. In the same way, other personality variables could be associated with health-protective behaviours (Bermudez, 1999).

In addition, the identification of such variables, and the analysis of their association with different kinds of behaviour, would permit the assessment of the individual's vulnerability and facilitate the identification of variables on which we should focus to improve the individual's health (Bermudez, 1999). Table 1 illustrates the personality variables consistently associated with non-adherence to oral health behaviours, while other variables tend to show a positive association with oral healthy behaviours.

Table 1. Influences of psychological variables on components of oral health behavior

Personality	Oral Health Behavior Promotion
Achievement motives (Hope of Success)	+
Affective lability	-
Aggression	+
Anger	+
Anxiety	-
Body appreciation	+
Body investment	+
Depression	-
Emotional intelligence	+
Happiness	+
Hope	+
Hostility	-
Mood/ Negative affect	-
Mood/ Positive affect	+
Perfectionism	+
Resilience	+
Self-consciousness	+
Self-control	+
Self-esteem	+
Self-liking	+

Personality	Oral Health Behavior Promotion
Self-regulation	+
Sensation seeking	+
Sense of hopelessness	-
Shyness	-
Sociability	-
Social desirability	+
Social inhibition,	-
Social intelligence	+
Social physique anxiety	-
Stress	-
Type A behavior pattern	+
Type C coping	-
Type D personality	-
Worry	-

2. Variable Approach

Personality factors may play a key role in explaining individual differences in health behaviors, with impulsivity, psychoticism, neuroticism, anxiety, and hostility having been associated with risky behaviors, while conscientiousness, agreeableness, optimism, hardiness, and self-efficacy have been shown to predict health-promoting behaviors (Bermúdez, 1999; Fusilier and Manning, 2005).

Anxiety disorders, such as generalized anxiety, panic disorders, obsessive-compulsive disorder, phobias or post traumatic stress disorder, are common and a major cause of disability. The lifetime prevalence of anxiety disorders is approximately 28.8% in the United States, with more than 1 of every 4 adults experiencing at least 1 anxiety disorder in their lifetime (Ernst, 2006; Devane et al., 2005).

Kurrer et al. (1995) examined the relationship between psychological mood (evaluated with the Hospital Anxiety and Depression Scale) and oral hygiene behavior in a group of 51 regular dental attenders. With regard to anxiety, subjects with higher and lowest scores showed a significant difference in gingivitis, though there was nothing approaching a difference in plaque scores. Several authors have shown interest in the study of the effect of anxiety on the etiology of periodontal disease (Vettore et al. 2003, Solis et al. 2004, Vettore et al. 2005, Johannsen et al. 2005, Castro et al. 2006) but conflicting outcomes were obtained. Recently, in a large sample of 31-yr-old-men and women born in Northern Finland in 1966 (n = 8463) Anttila et al. (2006) observed that symptoms of anxiety were significantly associated with lower toothbrushing frequency.

Type A behavior pattern (TABP) is a concept developed from Friedman and Rosenman's observation (Friedman and Rosenman, 1974) that certain behavioral attributes are associated with coronary heart disease (CHD). The typical TABP individual is highly competitive, achievement-oriented, impatient, reacts to frustration with hostility, feels pressured for time, is often involved in work and other activities subject to deadlines, and tends to be fast-moving and emphatic in speech. The constituents of TABP have been reported as: 1)

aggression-hostility, 2) hard-driving and time-urgency, and 3) speed-power (Friedman and Rosenman, 1959).

In a study performed by Freeman and Goss (1993) it has been shown that stress factors (type A behavior, lack of information regarding changes in the working environment, perception of physical ill health) in conjunction with cessation of smoking and toothbrushing frequency were related to an increase in pocket depth in a prospective study lasting 1 year. According to Axtelius et al. (1998) non-responsive periodontally treated patients had a more pronounced passive dependent personality than their successful counterparts. In contrast, limited impact of personality traits were demonstrated on clinical parameters to plaque accumulation and gingival inflammation during experimental gingivitis in young adults (Trombelli et al., 2005). In a sample of first-year students, Dumitrescu (2007) reported that mean levels of TABP in individuals with a toothbrushing frequency more than twice a day and who visited their dentist less than 6 months ago were higher than, but not statistically different from, those of individuals brushing less than once a day and who visited their dentist more than 2 years ago.

Hostility, a major attribute of the type A behavior pattern, has received considerable attention as a potential “toxic” element in this personality construct. Cynical hostility is manifested as a consistent lack of confidence in or bitterness with other people, and can be expressed as either a lack of confidence in other people or as a strong motivation and eagerness for change, but a lack of confidence. Also, people with cynical hostility have insufficient capability for anger expression (Mettovaara et al., 2006). It was shown that the subjects with the lowest cynical hostility level have a higher toothbrushing frequency than those with the highest level of cynical hostility ($p < 0.001$) (Mettovaara et al., 2006).

Anger refers to feelings of being treated unjustly and is accompanied by subjective arousal. In both clinical and non-clinical settings, excessive anger and dysfunctional anger expression have been linked to aggressive behavior, reduced social support, occupational stress and burnout, substance abuse, anxiety and depression, and a variety of physical and mental health problems: cardiovascular disease, osteoporosis, arthritis, type 2 diabetes, chronic pain, and certain cancers (Gatchel, 2004; Kiecolt-Glaser et al., 2002). It was shown that toothbrushing and mouth rinse frequency are significantly correlated with levels of anger, a primitive and archaic emotional reaction that bypasses the cognitive processes and may lead patients to behaviors (reduced oral health behaviors) that are, both symbolically and, in fact, self-destructive (Ciacci et al., 2002; Dumitrescu et al., 2008).

Aggression encompasses a wide variety of meanings, including different categories with different functions and antecedents (Ramírez 2005). Whether or not aggression is a deliberate attempt to injure someone, there seems to be a common dichotomy, in terms of purpose or goal, inferred or otherwise, between (1) instrumental aggression, which is anger-free and chiefly aims to obtain an object, such as some reward or advantage for the aggressor; and (2) hostile aggression, which is closer to anger because its primary goal is to hurt the victim (Ramírez, 2005). *Impulsivity* is often defined as ‘a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to negative consequences of these reactions to themselves or others (Moeller et al., 2001). Three components of impulsivity were identified: motor impulsiveness (acting on the spur of the moment and perseverance), cognitive (attentional) impulsiveness (the ability to focus on the task at hand and cognitive

instability), and non-planning impulsiveness (the inability to plan and think carefully) (Patton et al., 1995). *Sensation seeking*, is a biosocial dimension of personality characterized by “the need for varied, novel, and complex sensations and experiences and the willingness to take physical and social risks for the sake of such experiences” (Zuckerman, 1979). Students with higher aggression and impulsivity scores were more likely to brush their teeth less than once a day, but to floss their teeth every day, to use mouthrinses every day, to visit their dentist less than one month ago, but mainly when treatment is needed or when pain occurs. Significant differences were found between mean levels of aggression/verbal, aggression/hostility and aggression total in persons who floss their teeth everyday than in individuals who never use dental floss (Dumitrescu et al., 2007).

Type-D personality is a relatively new construct, developed in cardiac patients, that is characterized by the tendency to experience negative emotions paired with the propensity to inhibit self-expression in social interaction (Denollet, 2005). In cardiac patients, type-D has been associated with a variety of emotional and social difficulties, including depressive symptoms, chronic tension, anger, pessimism, low self-esteem, symptoms of fatigue, vital exhaustion, but also with impaired health status, increased morbidity and mortality (Denollet, 2005; Pedersen and Denollet, 2003; Schiffer et al., 2005; Aquarius et al., 2005; Pedersen et al., 2004; Denollet et al., 2000; 2003; 2006; Pedersen et al., 2004; 2006a; 2006b; Denollet and Van Heck, 2001; Conraads et al., 2005; Denollet and Brutsaert, 1998). A recent study of patients with chronic heart failure also showed that type-D patients are less likely to consult their cardiologist or heart failure nurse when experiencing an aggravation in their condition (Schiffer et al., 2007). When type-D personality as a determinant of health-related behaviors was evaluated, it was shown that type-D personality is associated with frequency of dental visits (Dumitrescu et al, 2007).

The personality of the *Type-C individual* is characterized by emotional control and a desire to please others, even at the expense of the individual's own needs. This suppressive style is thought to be linked with impaired endocrine and immune responses to chronic stress (i.e., cancer diagnosis), leading to the host's inability to resist disease onset/progression. The concept is closely connected to alexithymia, that can be described as the extreme strong tendency to suppress anger and other negative feelings. In addition to traits that were exclusively associated with cancer onset, the TABP and its components were also studied as a possible predictor of cancer incidence and cancer mortality. It was found the type C pattern significantly associated with thicker and more invasive malignant melanomas, a weaker lymphocyte response to the primary tumour, higher autonomic arousal in conjunction with lower self-report of perturbation, and greater disease progression when controlling for known prognostic indicators (Temoshok et al., 1985a; 1985b).

Stressors represented by major life events have been linked to neurotic impairment, coronary heart disease, cancer, and many other disorders: infectious diseases, inflammatory conditions, impaired wound healing and several disorders of the gastrointestinal system, such as gastric and duodenal ulcers, inflammatory bowel disease, irritable bowel syndrome (Pengilly and Dowd, 2000; LeResche and Dworkin, 2002; Clarke and Hirsch, 1995; Rozlog et al., 1999).

There is a growing body of evidence of clinical studies regarding the impact of psychosocial stressors on the health of the periodontium (Alesejuniene et al., 2002; Vettore et

al., 2003; Monteiro Da Silva et al., 1996; Moss et al., 1996; Croucher et al., 1997; Genco et al., 1999; Trombelli et al., 2005; Solis et al., 2004; Dolic et al., 2005; Klages et al., 2005; Castro et al., 2006; Vettore et al., 2003), much of which has focussed on teasing out the mechanism by which stress might affect the tissue, either through a direct change in physiology (Waschul et al. 2003, Kamma et al. 2004) or through changes in behaviour and their consequent impact on health (Deinzer et al. 2001, Hugoson et al. 2002), the putative mechanisms outlined by Genco et al. (1998). In adults (medical students) exposed to a specific event (major academic exam), known to increase subjective levels of stress, it was revealed heightened gingivitis expression that may relate to the stress-associated increase in plaque accumulation (Deinzer et al., 1998, 1999, 2001; Waschul et al., 2003).

More important than the stressful agents is how a person copes with stress. *Coping* is the response of subjects in an attempt to control, reduce, or avoid the negative or unpleasant effects of stress. Subjects who used emotion-focused coping strategies had more periodontal disease. These *emotion-focused coping* strategies include strategies such as consuming alcohol or drugs to make himself feel better; admitting that he/she can't deal with it and quit trying; and pretending that the problem hasn't happened. These emotion-focused strategies are "avoidance", and not likely to be effective in dealing with stress and are associated with low levels of well-being. *Problem-focused coping* is associated with high levels of well-being. This make also explain why those with high problem-focused coping behavior have less risk of periodontal disease, since they not only "make a plan of action", but also "take additional action to get rid of the problem" (Genco et al., 1999; Wimmer et al., 2002, 2005; Newton, 2005). It has been also showed that an individual's ability to cope with stressful stimuli (coping behavior), as measured by the beliefs of locus of control of reinforcements may play a role in the progression of periodontal disease (Hugoson et al., 2002). Locus of control has been defined as as the degree to which individuals perceive events in their lives as being a consequence of their own actions, and thereby controllable (internal control or internality), or as being the result of forces beyond their control, and therefore due to chance, fate or powerful others (external control or externality) (Monteiro da Silva et al., 1995).

Emotional intelligence (EI) is the ability or tendency to adaptively perceive, understand, regulate and harness emotions in self and in others (Schutte et al., 2001). EI is defined as "the subset of social intelligence that involves the ability to monitor one's own and others" feelings and emotions, to discriminate among them and to use this information to guide one's thinking and actions". EI is divided into three different areas: emotion awareness, competencies and values and beliefs, and each area are divided into different domains. The area of "emotional awareness" includes assessment of emotional self-awareness, emotional expression and emotional awareness of others as domains. The area of "competencies" includes assessment of intentionality, creativity, resilience, inter-personal connections and constructive discontent as domains. The area of "values and beliefs" included outlook, compassion, intuition, trust radius, personal power and integrated self as domains. An association between EI domains and short-term changes in plaque and bleeding was revealed being suggested that initial responses to standardized periodontal treatment may be partly related to EI (Gamboa et al., 2005). In a sample of first year students, Dumitrescu (2007) reported that mean levels of emotional intelligence in individuals who visited their dentist

less than 6 months ago were statistically higher than those of individuals who visited their dentist more than 2 years ago.

Resilience, the ability to bounce back or cope successfully despite substantial adversity, has received significant attention from various domains (Friborg et al., 2006;). Resilience is dynamic: successful coping in one situation strengthens the individual's competence to deal with adversity in the future (Garmezy, 1993; Richardson, et al., 1990; Rutter, 1993). Resilience is also developmental, changing with different stages of life (Egeland et al., 1993). After three decades of longitudinal research on resilience factors and mechanisms, three broad categories stand out as protective: (a) positive characteristics and resources of the individual; (b) a coherent, stable, and supportive family environment; and (c) a social network that supports and reinforces adaptive coping.) Students with higher resilience scores (Total scale and "Personal Competence" subscale) were more likely to floss their teeth more than twice a day, to use everyday mouthrinses and to visit their dentist for check-up or for tooth cleaning and scaling. The multiple linear regression analyses showed, for flossing frequency as dependent variable, a strong association with student's resilience and hope level (Dumitrescu in press).

Hopelessness is characterized by persistent negative feelings and expectations about the future as well as a loss of motivation. A sense of hopelessness seems to lead to more negative evaluations of new situations and less effective coping strategies, and thus the perception that one will not accomplish anything meaningful. Whether hopelessness represents a relatively severe constellation of depressive symptoms or can be distinguished from depression has been debated (Kubzansky et al., 2005). Hopeless participants were more likely to self-evaluate their dental health as poor/very poor, to be less satisfied by the appearance of their teeth, to have more non-treated caries, to brush their teeth once a day or less and to never use mouthrinses (Dumitrescu et al., in press).

Depressive syndromes and major depression are exceedingly common. Lifetime prevalence rates of major depression are estimated to be 20% in women and about 10% in men (Irwin, 2002). Episodes of major depression are characterized by the presence of depressed mood and markedly decreased interest in all activities, persisting for at least 2 weeks and accompanied by at least 4 of the following additional symptoms: changes in appetite, sleep disturbances, fatigue, psychomotor retardation or agitation, feelings of guilt or worthlessness, problems concentrating, and suicidal thoughts (Rozanski et al., 1999).

Various studies provide evidence of an association between depression and periodontal health (Monteiro Da Silva et al., 1996; Moss et al., 1996; Genco et al., 1999; Elter et al., 1999; Saletu et al., 2005; Klages et al., 2005; Marques-Vidal and Milagre, 2006). An explanation on the behavioural level might be that depressed patients neglect oral hygiene and regular dental check-ups as a result of reduced drive, mood, affectivity and interest (Kurer et al., 1995). In a large cohort study (8690 subjects) Ylostalo et al. (2003) showed that dental health behavior (frequency of dental check-ups and toothbrushing frequency) increases with strengthening life satisfaction and optimism. Anttila et al. (2006) reported that subjects with a high number of depressive symptoms had lower toothbrushing frequency as well as a lower frequency of dental visits than subjects with no or only a few depressive symptoms. Moreover, the self-perceived dental treatment need was more common among those with a high number of depressive symptoms.

Worry can be defined as “a chain of thoughts and images, negatively affect-laden and relatively uncontrollable” (Pallesen et al., 2006). In its more benign form, worrying appears to be a relatively common and possibly universal human experience that may even have some adaptive value. However, when worry becomes excessive and difficult to control, it can be very disturbing, self-defeating, and maladaptive (Belzer et al., 2002). Among oral health behaviors only toothbrushing and reason for not visiting regularly the dentist were influenced by worry total values and worry domains subscales (Dumitrescu et al., in press).

Mood and affect are terms that are often used interchangeably in the literature. Two dominant dimensions consistently emerge in studies of affective structure, both in the United States and in a number of other cultures. Although the terms *Positive Affect* and *Negative Affect* might suggest that these two mood factors are opposites (that is, strongly negatively correlated), they have in fact emerged as highly distinctive dimensions that can be meaningfully represented as orthogonal dimensions in factor analytic studies of affect (Watson et al., 1988). Briefly, Positive Affect (PA) reflects the extent to which a person feels enthusiastic, active, and alert. High PA is a state of high energy, full concentration, and pleasurable engagement, whereas low PA is characterized by sadness and lethargy. Positive and negative affect are increasingly be identified as distinctly different features of emotional experience in relation to a wide variety of health-related outcome measures. It was reported that positive affect was closely related to quality of life-as-a-whole and to well-being therapy (Belaise et al., 2005; Karatzias et al., 2006). Students with higher levels of positive affect were more likely to brush their teeth less more than twice a day, to floss their teeth everyday and to visit their dentist mainly for check-up or for tooth cleaning and scaling. In contrast, higher levels of negative affect were associated with visit to their dentist mainly when treatment is needed or when pain (Dumitrescu et al., 2008).

The past several decades have witnessed an explosion of research on *happiness* (or more broadly defined as subjective well being, as it has been typically referred in the literature). As noted, most individuals are capable of reporting on the extent to which they are a happy person (or an unhappy one), and this judgment is likely not equivalent to a simple sum of their recent levels of affect and their satisfaction with life. It was noted the importance of *subjective* processes in happiness, as some people consider themselves happy in spite of personal obstacles, tragedy, or lack of any great love or wealth, while others perceive themselves as unhappy despite being surrounded by all of life’s comforts and advantages (Lyubomirsky, 2001). In a sample of undergraduate students it was observed that participants who reported to floss their teeth daily and to visit their dentist mainly for check-up or for tooth cleaning and scaling reported higher scores on Satisfaction With Life Scale and Subjective happiness scale when compared with those who never used dental floss and who visit their dentist when treatment is needed or when pain (Dumitrescu et al., in press).

Self-esteem is described by Rosenberg (1965), who postulates that an individual with high self-esteem respects himself, considers himself to be at least on an equal plane with others, recognizes his own limitations and expects to grow and improve. Research has linked high self-esteem to many positive outcomes, including occupational success, healthy social relationships, subjective well-being , positive perceptions by peers, academic achievement, persistence in the face of failure and improved coping and self-regulation skills (Trezesniewski et al., 2003). In the dental sphere, higher self-esteem has been observed to be

associated with higher frequency of tooth brushing (Macgregor et al. 1997; Källestål et al., 2000; Knecht et al., 2001). Concerning dental visiting, the results are contradictory, some have found associations between self-esteem and dental visiting (Regis et al. 1994), while Knecht et al. (2001) did not find associations with compliance with dental appointments. Controversy, low self-esteem has been linked to a number of problematic outcomes, including depressive symptoms, health problems and antisocial behavior (Trezesniwski et al., 2003). The level of instability of self-esteem failed to show a consistent association with oral health behaviours (Dumitrescu et al., 2008). Tafarodi and colleagues (2002) have demonstrated that the most common measure of global self-esteem actually measures two distinct, though related, constructs - self-competence and self-liking - with a distinct bias toward the latter (Tafarodi and Milne, 2002, Tafarodi and Swann, 1995).

Body image is a multifaceted construct that refers to individuals' perceptions of and attitudes toward their own body, especially its appearance. It is contended that, from early childhood and on, cognitive and affective aspects of the bodily self develop in a mutual complementarity to form the general sense of self. The body and mental-self relationship is evidenced in many mental disturbances involving physical self-harm (Orbach and Mikulincer, 1998). The higher the self-esteem, the more positive the body image feelings and attitudes, the more touch comfort, and the higher the body care (Dumitrescu et al., in press). In a sample of undergraduate students it was revealed an association between self-liking, self-competence, *body investment* subscales and flossing, mouthrinse, dental visit pattern. Toothbrushing frequency once a day or less was observed in persons with low-levels of self-liking, body care and body protection (Dumitrescu et al., in press). Despite the attention given to people's perceptions of and feelings about their bodies, little consideration has been given to people's concerns with others' perceptions of their bodies (Hart et al., 1989). The anxiety associated with perceived social evaluation of one's body or physical appearance has been labeled *social physique anxiety*. It was revealed the persons with high levels of social physique anxiety visited their dentist more than 2 year ago and mainly for treatment or for pain (Dumitrescu et al., submitted).

Perfectionism is a multidimensional construct. Frost and his colleagues (1990) defined perfectionism as the desire to achieve the highest standards of performance, in combination with unduly critical evaluations of one's performance. Six dimensions were individuated: personal high standards, concern over mistakes, parental criticism, parental expectations, doubts, and organization. According to these authors, concern over mistakes is the distinguishing feature of pathologic perfectionism. Pathologic perfectionists allow little room for making mistakes and perceive even minor ones as likely to lead to a future final failure (Sassaroli, and Ruggiero, 2005). Toothbrushing frequency once a day or less was observed in persons with low-levels of perfectionism (Dumitrescu et al., in press).

The consistent tendency of persons to direct attention inward or outward is the trait of *self-consciousness* (Fenigstein et al., 1975; Park et al., 2006). This trait can be divided into private and public components. Private aspects of the self are covert and personal, including attitudes, motives, and feelings, whereas public aspects are more overt and observable by others, including appearance and behavior. Although private and public *self-consciousness* are considered to be independent constructs, they have been found to be moderately positively related to each other (Fenigstein et al., 1975; Park et al., 2006). In a sample of first

year medical students, significant differences were found in Public, Total Self-Consciousness and Social Anxiety according to reason for dental visit. Oral health behaviours such as tooth brushing, flossing, mouth washing and last dental visit were not influenced by each of the self-consciousness subscales (Dumitrescu et al., 2008).

Paulhus (1984, 1994) suggests that there are two distinguishable dimensions of *social desirability*: (a) Self-Deception, which is the unconscious tendency to see oneself in a favorable light (both by promoting one's positive qualities and disavowing negative qualities (Paulhus and Reid, 1991), and (b) Impression Management, which is a conscious self-presentation tailored to an external audience. Both of these aspects of social desirability might conceivably influence responses on self-report measures, and impression management efforts might also influence the perceptions that drive ratings by others (Tan and Hall, 2005; Gravdal and Sandal, 2006; Peterson et al., 2006). In a sample of undergraduate students it was revealed that social desirability was correlated with reason for dental visit (Dumitrescu et al., 2008).

Social intelligence was first defined by Thorndike in 1920 (Thorndike, 1920) as "the ability to perceive one's own and others' internal states, motives and behaviours, and to act toward them optimally on the basis of that information". Together with cognitive intelligence, emotional and social intelligence form important components of general intelligence. One of the major differences between the two is that the former is thought to relate primarily to higher order mental processes like reasoning, while the latter focuses more on perceiving, immediate processing and applying emotional and social content, information and knowledge (Bar-On et al., 2003). Undoubtedly, social intelligence is a multifaceted construct and, among others, Björkqvist et al. (2000) and Weiss and Süß (2007) argued that social intelligence has three different components: perceptual, cognitive-analytical and behavioural. It was reported that students who brushed their teeth more than twice a day presented higher levels of social awareness than participants that brushed their teeth once a day or less. It was also observed that persons who flossed their teeth everyday presented higher values of social skills and social awareness than individuals that never used dental floss. Participants that visited their dentist mainly for check-up or for tooth cleaning and scaling scored much higher on social skills than participants that were approached their dentist only when treatment is needed or when pain (Dumitrescu et al., 2008).

One of the most salient behavioral characteristics of individuals in social contexts is their tendency to approach conspecifics or to withdraw from them. *Sociability* is a preference for affiliation or need to be with people, and shyness is the discomfort and inhibition that may occur in the presence of others. *Shyness* has been denned as an emotional-behavioral syndrome characterized by social anxiety and interpersonal inhibition or avoidance. Shyness frequently has been distinguished from low sociability—a *nonfearful* preference for not affiliating with others (Eisenberg et al., 1995). Both, sociability and shyness are correlated with dental visit pattern (reason and frequency) (Dumitrescu et al., submitted).

According to *social comparison* theory (Festinger, 1954), people who are uncertain about themselves have a stronger motivation to evaluate their opinions, attitudes, and behaviors with respect to others (Gibbons and Buunk, 1999; Thau et al., 2007). Although the majority of research has understood social comparisons as driven by situational factors, some people are more and others less likely to compare themselves with others across different social

domains (Thau et al., 2007). No correlation was revealed between social comparison and oral health behaviours (Dumitrescu et al., submitted).

Self-control skills were defined as the interdependent operations of self-monitoring, self-evaluating, and self-reinforcing (also referred to as *self-consequating* because it includes self-administered punishment). Self-control skills are deemed critical for personal adjustment when environmentally controlled reinforcement is delayed or absent. More generally, self-control skills involve the ability to initiate or persist in a low-probability target behavior in opposition to competing higher probability behaviors and without the aid of contingent environmental reinforcement or support (Mezo and Heiby, 2004). In a sample of undergraduate students it was demonstrated that self-control was associated with mouthrinse frequency (Dumitrescu in press).

Human beings sometimes engage in activities just for the sake of finding out whether or not they are capable of performing an activity successfully. Such *achievement-motivated* behavior can be characterized by a concern with a standard of excellence that is important to the individual. The underlying achievement motive is understood as a generalized evaluative and behavioral tendency in situations in which a standard of excellence can be applied. There is a consensus in the literature that the achievement motive splits into an approach and an avoidance tendency. Typically, the approach tendency is labeled hope of success (HS) and the avoidance tendency is called fear of failure (FF) (LangandFries, 2006). Dumitrescu et al (in press) revealed that persons who brush their teeth more than twice a day and visit their dentist less than 6 months ago present higher values of hope of success when compared with individuals who report their toothbrushing frequency to be once a day or less and visit their dentist 1-2 years ago.

3. Process Approach

A. Current Models of Individual Self-Protective Behavior Theoretical Models

To answer these questions, a number of theoretical models have been formulated: the Health Belief Model (HBM) (Becker, 1974; Becker and Maiman, 1975; Janz and Becker, 1984; Rosenstock, 1974, 1990; Rosenstock et al., 1988), the Protection Motivation Theory (PMT) (Maddux and Rogers, 1983; Rogers, 1975, 1983), the Precaution Adoption Process (PAPM) (Weinstein, 1988, 1993; Weinstein and Nicolich, 1993; Weinstein et al., 1990), the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), the Theory of Planned Behavior (TPB) (Ajzen, 1985, 1988), the Subjective Expected Utility Theory (SEUT) (Edwards, 1954), and the Comprehensive Health Seeking and Coping Paradigm (CHSCP) (Nyamathi, 1989) (Bermudez, 1999). These models have been applied to a variety of health-related behaviours such as leisure activities, participation in screening programmes, programmes of regular physical activity, compliance with medical regimens, driving, smoking, and alcohol consumption behaviour, risky sexual behaviour, etc (Bermudez, 1999).

The basic assumption of stage models is that behaviour change is a process that can be divided into distinct stages. For example, these stages describe the development of an

intention to change, initiation and maintenance of a health behaviour and, finally, recovery after lapses. Whereas models such as the PAPM provide seven stages, other approaches such as the health action process approach (HAPA; Schwarzer, 2001) propose only two stages (Sniehotta et al., 2005). Some stages of the PAPM are similar to those of the transtheoretical model (TTM; Prochaska and DiClemente, 1982). In contrast to stage models, continuum models such as the theory of planned behaviour assume no distinction of the process of change into stages. In continuum models, the likelihood of a specific health behaviour can be predicted from a given set of attitudes, competencies, and beliefs. Thus, a change in these constructs corresponds with behaviour change (Sniehotta et al., 2005). Researchers who emphasize the utility of continuum models suggest that the distinction between stages is arbitrary and in most cases not sufficiently based on empirical evidence (Sniehotta et al., 2005).

1) *The Health Belief Model (HBM)*

The HBM has been thoroughly evaluated, has received empirical support and is considered to be one of the most influential models in health promotion (Roden, 2004). It originated in the 1950s to explain why people would not participate in programs to prevent or detect disease (Hochbaum, 1958; Strecher and Rosenstock, 1996). At a later stage, Becker et al. (1974) extended the application of the HBM to include people's responses to symptoms and Becker and Maiman (1975) included people's responses to illness and compliance with medical directions. Thus, the initial model was extended to include screening behaviors, all preventive health actions and illness behaviors (Becker et al., 1974; Rosenstock, 1974b; Becker and Maiman, 1975; Maiman et al., 1977; Janz and Becker, 1984; Roden, 2004).

The significant constructs in the HBM are:

- “Perceived susceptibility”, referring to one's subjective perception of the risk of contracting a condition or disease.
- “Perceived severity”, associated with feelings about the seriousness of acquiring an illness in terms of medical and social consequences.
- “Perceived benefits”, based on beliefs regarding the effectiveness of the particular actions available in reducing the threat of disease/illness.
- “Perceived barriers”, referring to the cost-benefit analysis which it is believed people undertake to weigh up a beneficial action and its opposing limitations such as costs, side-effects, time and inconvenience.
- “Cues to action” (which instigate preventive health activity), where levels of susceptibility and severity provide the stimulus to act and the perception of barriers offer a preferred mode of action.
- “Modifying factors” defined as demographic, socio-psychological and structural, as being those which serve to condition an individual's perceptions about perceived benefits of preventive health actions (Roden, 2004).

Many criticisms have been leveled at the HBM, including its social psychology connections; the assumption that individuals undertaking health behaviors do so in a rational or conscious way; the lack of evidence to support the belief behavior relationship; the

difficulty associated with modifying beliefs and no suggestion of strategies for change; the focus on individual factors in terms of health intervention, rather than considering socio-environmental factors as well; limitations with logical explanation, clarity and accuracy of the HBM due to unclear construct and relationship development; the notion of ‘engineering’ individuals into preventive health behaviors and how this influences future behavior and; the encouragement of victim blaming because of the HBM’s focus on the individual’s part in determining behavior (Roden, 2004).

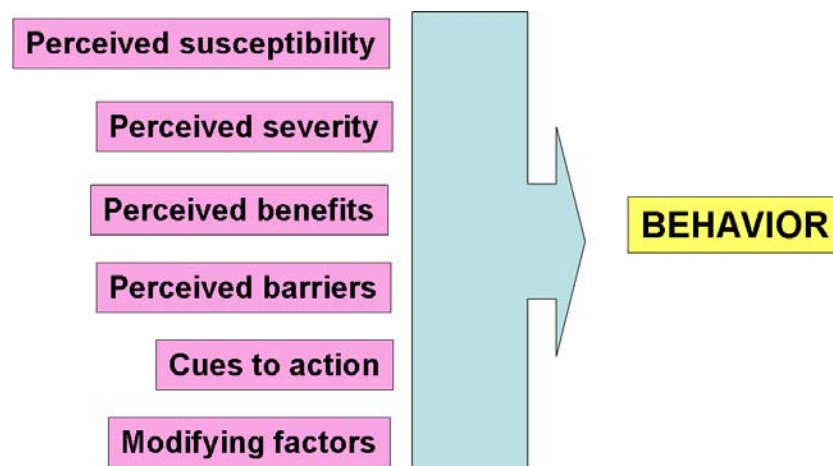


Figure1. The Health Belief Model.

2) The Protection Motivation Theory (PMT)

The Protection Motivation Theory (PMT) was developed based on expectancy-value theory (Rogers, 1975) and revised to include reward and self-efficacy components (Maddux and Rogers, 1983; Rogers, 1983). Inputs to the model include environmental sources of information (e.g., verbal persuasion and observational learning) and intrapersonal sources (e.g., personality aspects and feedback from prior experience). Prior experience includes feedback from personal experiences associated with the targeted maladaptive and adaptive responses (Floyd et al., 2000).

PMT is organized along two cognitive mediating processes: the threat-appraisal process and the coping-appraisal process. Assessments of threat and coping factors combine to form the intervening variable protection motivation. Protection motivation is similar to other types of motivation in that it arouses, sustains, and directs activity (Floyd et al., 2000).

The threat-appraisal process is addressed first, since a threat must be perceived or identified before there can be an evaluation of the coping options. Threat appraisal evaluates the maladaptive behavior. Factors comprising the threat-appraisal process are maladaptive response rewards (intrinsic and extrinsic) and the perception of threat (severity and vulnerability). Rewards will increase the probability of selecting the maladaptive response (not to protect the self or others). whereas threat will decrease the probability of selecting the maladaptive response (Floyd et al., 2000).

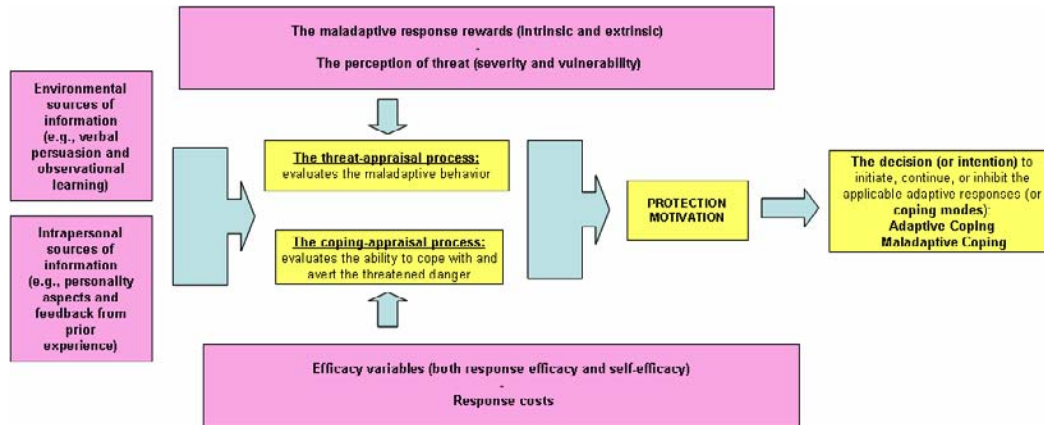


Figure 2. The Protection Motivation Theory.

The coping-appraisal process evaluates the ability to cope with and avert the threatened danger. Factors comprising the coping-appraisal process are efficacy variables (both response efficacy and self-efficacy) and response costs. Response efficacy is the belief that the adaptive response will work, that taking the protective action will be effective in protecting the self or others. Self-efficacy is the perceived ability of the person to actually carry out the adaptive response. Response costs are any costs (e.g., monetary, personal, time, effort) associated with taking the adaptive coping response. Response efficacy and self-efficacy will increase the probability of selecting the adaptive response, whereas response costs will decrease the probability of selecting the adaptive response (Floyd et al., 2000).

The output of these appraisal-mediating processes is the decision (or intention) to initiate, continue, or inhibit the applicable adaptive responses (or coping modes). Thus, the typical dependent variables in research on PMT are measures of behavioral intentions (Rogers and Prentice-Dunn, 1997). The purpose of PMT research is usually to persuade people to follow the communicator's recommendations; so, intentions indicate the effectiveness of the attempted persuasion (Floyd et al., 2000).

A primary difference between the HBM and PMT is the way in which the two are organized. The HBM is organized as a catalog of variables contributing to behavior. PMT is organized along two processes that attempt to match the cognitive processes that people use in evaluating threats (the threat-appraisal process) and in selecting among coping alternatives (the coping-appraisal process) (Floyd et al., 2000).

3) The Precaution Adoption Process (PAPM)

The Precaution Adoption Process Model (PAPM), is based on the stages of change concept. The seven-stage PAPM, unlike other health behavior theories where a person is either practicing or not practicing the behavior, conceptualizes behavior change as dynamic and occurring over time (Weinstein, 1988, Weinstein and Sandman, 2002; Blalock et al., 1996). Stage 1 (unaware of issue) describes a state in which a person is not aware of a potential health threat or a protective behaviour. A stage of unawareness is specific to the PAPM and it has not been studied sufficiently (Weinstein, 1988). If an individual is aware of the issue but not personally engaged, then Stage 2 (unengaged by issue) is reached. Stage 3

(deciding about action) is characterized by deliberations about costs and benefits. This stage is similar to the contemplation phase, described in the transtheoretical model. If this decision is negative, the person abandons the process of change and reaches Stage 4 (decided not to act). If the decision is positive, the person forms an intention and progresses from Stage 3 to Stage 5 (decided to act). The two action stages of the PAPM are similar to the ones in the transtheoretical model. Stage 6 (acting) refers to initiation of the action, and Stage 7 (maintenance) describes additional stabilization of initiated actions. According to the assumptions of the PAPM, successful behaviour change requires that an individual passes through the stages in a sequence of 1, 2, 3, 5, 6, 7, without skipping a stage (Sniehotta et al., 2005). However, there is no minimum amount of time one will spend in each stage and people can regress in their stage (Elliott et al., 2007).

The PAPM (and other stage models) suggest that people at different points in the precaution adoption process behave in qualitatively different ways and that the types of interventions and information needed to move people closer to action varies from stage to stage. Although the PAPM does not provide a fixed set of variables that differentiate between stage or foster progression from stage to stage, it is thought that between stages an individual's health beliefs and perceptions (perceived susceptibility, perceived severity, barriers, benefits and self-efficacy) are critical for action. People in action and maintenance have often changed their behavior and in these stages self-efficacy (confidence in abilities) is likely based on experience rather than perception.

The PAPM has been used to study adoption of behaviors related to osteoporosis, and home radon testing (Weinstein, 1988, Weinstein et al., 1998; Sharp and Thombs, 2003; Mauck et al., 2002; Elliott et al., 2007).

4) *The Theory of Reasoned Action (TRA)*

According to the Theory of Reasoned Action, intention is the best predictor of subsequent (volitional) behavior. Intentions are based on the individual's attitude toward performing the behavior and perceived social norms about performing the behavior. Attitude is based on a set of outcome beliefs about the consequences of behavior: how good or bad each outcome is, and how likely it is to occur. A perceived social norm is based on a set of normative beliefs: whether particular referents approve or disapprove of the behavior and how motivated the individual is to comply with each of these referents.

The TRA makes strong and testable statements of sufficiency: All other variables that affect intention work through attitude, perceived norms, or both, and attitude and perceived norms affect behavior only through intention. Designing interventions based on this model involves working backward through the paths to the constituent cognitions, identifying outcome and normative beliefs that are potentially changeable, and delivering interventions that change those beliefs (Morrison et al., 2002).

5) *The Theory of Planned Behavior (TPB)*

The Theory of Planned Behavior extends Fishbein and Ajzen's (1975) Theory of Reasoned Action by including a confidence variable, that is: "confidence in one's own ability to carry out the action". The strength of the individual's intention to perform a particular

behavior is dependent on the more favorable the attitude and subjective norm in terms of the behavior (Roden, 2004).

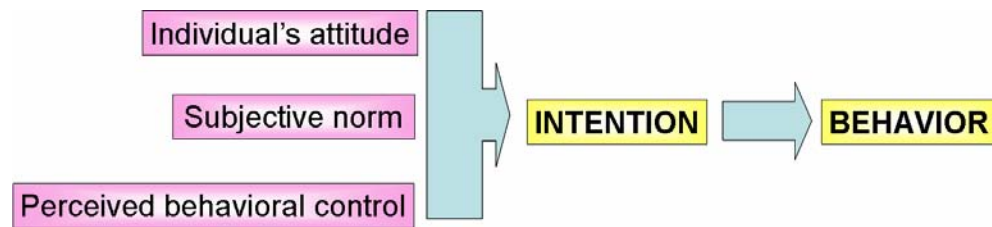


Figure 3. The Theory of Planned Behavior.

The Theory of Planned Behavior concerns an individual's behavior being determined by his/her intention to perform that particular behavior. There are three determinants that influence behavioral intention. The first is the *individual's attitude* (positive or negative) towards performing the behavior under consideration, which Fishbein and Ajzen (1975) suggest is the relation between a set of beliefs (N) about performing a behavior and attitude towards that behavior. The second determinant is that of *subjective norm* or the individual's belief about the importance significant others, such as a partner or co-worker, place on the performance of that particular behavior. The third and final determinant is the degree of *perceived behavioral control* or the perceived ease or difficulty in performing the specific behavior. This third determinant is the additional factor which distinguishes the Theory of Planned Behavior from the Theory of Reasoned Action (Roden, 2004).

The PAPM has been used to study behaviors related to coronary heart disease (Johnston et al., 2004), drinking among college students (Collins and Carey, 2007), chronic kidney disease (Eng and Ginis, 2007), colorectal cancer (Courneya and Friedenreich, 1997), smoking (Norman et al., 1999) and condom use (Sutton et al., 1999).

6) The Subjective Expected Utility Theory (SEUT)

The subjective expected utility model begins with the premise that *whenever helping behavior is under intentional control*, situational factors or other experimental operations that affect such behavior do so by affecting one or more of three aspects of the situation: (a) the subjective probabilities (P) of one or more consequences that will follow from helping or not helping; (b) the utilities (U) or subjective evaluations of those consequences; and (c) the salience of those consequences. In general, a utilitarian approach to understanding behavior assumes that when people choose from among various behavioral alternatives, they always try to select the course of action whose *consequences* will give them the greatest *utility*. The decision maker combines information (i.e., subjective probabilities and utilities) for all of the salient consequences of making a given choice and from this information forms an impression of the subjective expected utility of that choice. Presumably the decision maker evaluates all salient alternatives in this fashion and then chooses the one with the greatest SEUT (Edwards, 1954; Lynch and Cohen, 1978).

7) *The Comprehensive Health Seeking and Coping Paradigm (CHSCP)* (Nyamathi, 1989)

In the Comprehensive Health Seeking and Coping Paradigm, six components are predictors of risk behaviors. The first five components are personal resources, social resources, cognitive appraisal, coping behavior, and in the case of Latinas, the socio-demographic factor of acculturation to the Anglo culture. *Personal resources* include self-esteem and emotional disturbance. Social resources, such as social support, provide another important dimension influencing health-seeking behaviors and health outcomes (Nyamathi et al., 2003).

Coping responses are defined as the cognitive and behavioral efforts to manage internal or external demands seen as taxing or exceeding the resources of the person. These responses can be described as active or adaptive coping behaviors that manage problems or avoidant behaviors that ease the emotional distress experienced (Nyamathi et al., 2003). Research has outlined the relationship between self-efficacy, coping sense of coherence and oral health status and behaviours (Wolfe et al., 1996; Savolainen et al., 2004, 2005; Ayo-Yusuf et al., 2008).

8) *Health Promotion Model (HPM)*

The health promotion model represents a theoretical perspective that explores the factors and relationships contributing to health-promoting behavior and therefore to the enhancement of health and quality of life. The health promotion model, originally developed in the early 1980s by Pender (Pender, 1996; Pender et al., 2002, 2005) is a framework that serves as “a guide for exploration of the complex biopsychosocial processes that motivate individuals to engage in health behaviors directed toward the enhancement of health” (Srof and Velsor-Friedrich, 2006).

The HPM classifies health behavior determinants into three specific propositional groupings: (a) individual characteristics and experiences, (b) behavior specific cognitions and affects, and (c) situational/interpersonal influences. The individual characteristics and experiences are innate factors (gender, age, genetics), as well as experience factors that inform future behavior. These background factors are largely unmodifiable. The behavior-specific cognitions and affect category includes perceived benefits-barriers to behavior, perceived self-efficacy, and affect cues to behavior (Srof and Velsor-Friedrich, 2006). These factors are the target of most of the HPM research to date. The situational and interpersonal influences are social and environmental factors that influence health behavior (Pender, 1996; Pender et al., 2002, 2005; Srof and Velsor-Friedrich, 2006). It has been reported that self-efficacy is associated with oral health behaviours (Syrjälä et al., 2001, 2004).

B. A Dynamic Perspective: Psychological Process and Behavior Sequence

Practically all these models share a common general hypothesis: namely, that human behaviour is basically rational and intentional. Therefore, it is expected that first, to engage in a new behaviour, or to modify a current behaviour, people develop a set of cognitive, affective, and motivational processes, in the wake of which they make the decision to carry

out a given course of action. Second, once the decision has been made, the behaviour consistent with such a decision will be carried out automatically (Weinstein, 1988; Bermudez, 1999).

Decision Making

Basically, the process of making a decision is supposed to be based on the analysis and evaluation of the following factors: (i) the possible courses of action; (ii) the potential consequences associated with each alternative course; (iii) the availability of resources to achieve or to avoid such consequences, (iv) the cost±benefit balance associated with each behavioural option, and (v) the social influences and pressures in favour of or against the course of action one has decided to carry out (Weinstein, 1988; Bermudez, 1999).

Decision-making could be influenced by the following processes: cognitive (e.g. expectations, perception of the situation, etc); social (e.g. social pressure factors, social support network, etc); motivational (e.g. incentive and value of the goal etc); and affective (e.g. emotional consequences of the previous processes). The post-decisional stage, in its turn, would be affected substantially by motivational processes (volitional and self-regulatory strategies), as well as the additional contribution of the other factors (Weinstein, 1988; Bermudez, 1999).

Once the decision of carrying out protective health behaviour has been made, the implementation and maintenance of this behaviour will depend substantially on the availability of self-regulatory strategies and on the capacity to exercise them, in addition to other motivational factors such as the goal's importance and value, one's self-confidence level, or the strength of the behavioural intention (Weinstein, 1988; Bermudez, 1999).

Behavior Initiation

The initiation of behaviour consistent with the intention would be facilitated by forming call 'implementation intentions'. An implementation intention supposes its contextualized formulation, making explicit when and under what circumstances the necessary behaviour to reach the goal will be carried out (Weinstein, 1988; Bermudez, 1999).

Behavior Persistency

Behaviour persistency until the goal has been reached, on the other hand, would be favoured by the use of other strategies directed, first, at maintaining the motivational value of the intention and, second, at preserving behaviour from possible interferences from other goals and introducing necessary adjustments to achieve the greatest possible fit between intention and behaviour, between programmed and actual behaviours (Bermudez, 1999). From this perspective it is expected that persistency of intended behaviours will be facilitated provided that individuals (i) focus their attention on goal attractive aspects, (ii) emphasize the positive affective correlates associated with the intention accomplishment, minimizing or ignoring the affective correlates associated with possible alternative behaviours or failing to carry out the intention, (iii) set or choose situations that favour intention completion, (iv) plan realistic goal behaviour, setting subgoals that permit feedback and short-term reinforcement, (v) monitor their behaviours to detect and correct possible discrepancies between intention

and behaviour, and (vi) reinforce themselves in light of their own achievements (Weinstein, 1988; Bermudez, 1999).

It is not infrequent, however, to observe significant discrepancies between intention and actual behaviour. Among the possible reasons to account for these discrepancies, the following three have been suggested. First, the intention statement may not be sincere. Second, there may be an interfering effect of affective processes activated by the information and/or future expectations associated with the behaviour. And third, maybe the psychological processes guiding decision-making are not the same as those driving and maintaining behaviours consistent with that intention (Weinstein, 1988; Bermudez, 1999).

C. Intention-Behaviour Discrepancies

Risk Perception Dimensions

Risk in the modern world is perceived and acted on in two fundamental ways. *Risk as feelings* refers to individuals' fast, instinctive, and intuitive reactions to danger. *Risk as analysis* brings logic, reason, and scientific deliberation to bear on risk management (Slovic et al., 2004).

The role of risk perceptions in shaping health behaviors is a fundamental, undecided issue in health psychology. Neither theories of health behavior nor empirical studies appear to agree about the importance of these perceptions. Risk perception is central to most health-specific behavioral theories including the health belief model (Rosenstock, 1974), protection motivation theory (Rogers, 1975), and the extended parallel process model (Witte, 1992). Similarly, the self-regulation model (Leventhal et al., 1980) includes several constructs important to risk perception (Cameron, 2003; Brewer et al., 2007).

Perceptions of risk vary considerably among people and frequently show little correspondence to epidemiological findings or accident statistics; moreover quantitative risk judgments are prone to a number of biases. First, small probabilities are overestimated, and large probabilities are underestimated. Second, risks that are more cognitively "available" due, for example, to personal experience or media coverage tend to be overestimated. This can be related to the availability heuristic which refers to the tendency for an event to be judged more probable to the extent that it is more easily pictured or recalled. Thus, estimates of the likelihood of "sensational" risks such as the risk of contracting AIDS or being involved in an air crash tend to be too high, while estimates tend to be too low for more common and/or less sensational risks such as heart disease or being involved in a traffic accident (Pligt, 1996).

Various studies showed that there is a general tendency for people to underestimate their risk. Generally, however, people have a reasonable idea of the *relative* risks of various activities and behaviors. Major errors seem to occur primarily in estimates of the *magnitude* of the risks. This relative accuracy of perceived risk seems to support the central role of this concept in models of health behavior (Pligt, 1996).

Most research on biases in perceived risk focuses on cognitive factors, and tends to ignore motivational factors that may influence the perception of risk. Although people seem quite aware of the *relative* risk of specific activities or behaviors, things tend to change when

this knowledge is applied to their own behavior. For instance, many smokers accept the association between smoking cigarettes and disease, but do not believe themselves to be personally at risk. Motivational explanations of this perceived vulnerability tend to focus on the need to reduce feelings of fear and anxiety. Support for the role of these mechanisms is provided by research showing more biased risk estimates in situations of increased threat (Pligt, 1996).

A second and less obvious problem arises from the fact that correlations between risk perceptions and risk behaviors within a population can change over time even when the factors that govern behavior remain the same. These changes occur because the status of people is not frozen. When people learn about a risk or learn about a new way of reducing a risk, they may change their actions and then alter their risk perceptions to match their new behavior. Such changes in risk behaviors and risk perceptions lead to changes in the correlations between these variables (Weinstein and Nicolich, 1993).

The nature of some of these temporal changes can be anticipated. After a hazard becomes apparent or a new precaution becomes available, some people will probably act to lower their risk. The people who remain at risk are likely to have fewer attributes that favor preventive action and more attributes that favor high-risk behavior; they are not representative of those who were originally at risk. Some people may remain at high risk even though they acknowledge considerable danger. Their failure to lower their risk status may reflect the presence of barriers that inhibit protective action rather than the irrelevance of risk perceptions to their decisions about prevention (Weinstein and Nicolich, 1993).

Individuals typically exhibit “unrealistic optimism”, the belief that they are less likely than the average person to experience a negative event. Why does unrealistic optimism occur? One possible explanation, motivational in nature, is that individuals draw the UO conclusion because they want to, since it brings them comfort. Fearing that they may suffer the negative event in question, they deliberately distort their reasoning to arrive at the thought that they are at less risk than the average person. This serves to reassure them (Gold, 2008).

Clarke et al. (2000) reviewed several studies of unrealistic optimism that have assessed perceived personal risk in relation to a series of negative outcomes including susceptibility to illness, serious injury in an automobile accident, and alcohol problems, perceived risk of heart disease, lung cancer and alcoholism and concluded that such optimism occurs in relation to a variety of unrelated potential risks. Other researchers have focused on a single risk, such as developing smoking-related illnesses, developing skin cancer from sunbathing, contracting AIDS, or being involved in a serious automobile accident (Kreuter and Strecher, 1995). Unrealistic optimism can also occur in relation to positive events, with individuals seeing themselves as more likely to experience financial success or longevity (Kreuter and Strecher, 1995).

Six possible causes have been mentioned in the literature on unrealistic optimism. The first is *perceived control*: When rating one's own risk status as compared to others, optimism tends to be greater for those risks judged to be under personal control. Research findings also indicate that those who rate the controllability of a specific risk higher also tend to be more optimistic about that risk. A second factor that is often related to optimism is the so-called *egocentric bias*. When people are asked to assess their risks and those of others, they generally have more knowledge about their own protective behaviors than about those of

others. It seems that people tend to focus on their own risk-reducing practices and are less aware of personal actions or circumstances that increase their risks. The fact that one's own actions are more available than those of others reduces the awareness that many other people also take protective action. Third, *personal experience* with a specific risk tends to decrease unrealistic optimism. Personal experience tends to be relatively vivid as compared to statistical information about risks, and enhances both availability and recall. A fourth factor that could produce unrealistic optimism is related to *stereotypical or prototypical judgment*. People might have a relatively extreme image of high risk groups or those suffering from specific diseases. This extreme prototype is unlikely to fit one's self-image, hence the tendency to infer that the risk primarily applies to others. A fifth factor is *self-esteem maintenance* or enhancement. The sixth and final factor that could cause optimism is related to *coping strategies*. Under conditions of high stress or threat, denial is a response often used to protect against anxiety and/or worry. Denial can reduce emotional distress but also reduces the likelihood of preventive actions, which may be necessary to reduce one's risks. According to this explanation, unrealistic optimism is an illusion that can help the individual to adapt the threatening events (Pligt, 1996).

Less is known about pessimistic biases. People with pessimistic biases about their health—the so-called "worried well"—tend to overestimate their risk of health problems. How might pessimistic biases influence a person's health-related behaviors? People with pessimistic biases may suffer undue stress and anxiety, and their unwarranted concern may lead them to greater use of health care services. Ideally, health promotion interventions ought to reduce both optimistic and pessimistic biases (Kreuter and Strecher, 1995).

Can unrealistic perceptions of risk be changed? Several strategies for communicating risk more effectively were recommended: (a) strongly emphasize the link between behavior and susceptibility, (b) provide specific behavioral objectives, and (c) provide descriptions of the preventive actions of others (Kreuter and Strecher, 1995).

Feelings as Determinants of Behavior

Theories of decision making have also recently focused on affect (Chapman and Coups, 2006). Examples include *decision affect theory* (Mellers and McGraw, 2001; Mellers et al., 1999), in which choices are guided by the anticipated emotional reaction to consequences; the *affect heuristic* (Slovic et al., 2005), in which fast, intuitive, affective processes guide decision making in situations of stress or cognitive load; and the *risk-as-feelings hypothesis* (Loewenstein et al., 2001), which proposes that anticipatory emotion experienced at the point of decision making often drives behavior, rather than a cognitive assessment of the risks (Chapman and Coups, 2006; Forgas, 1995).

People react to the prospect of risk at two levels: they evaluate the risk cognitively, and they react to it emotionally. Although the two reactions are interrelated, with cognitive appraisals giving rise to emotions and emotions influencing appraisals, the two types of reactions have different determinants. Cognitive evaluations of risk are sensitive to the variables identified by decision theory, namely probabilities and outcome valences. Although emotions do respond to cognitive evaluations, they can also arise with minimal cognitive processing and people can experience fear reactions without even knowing what they are afraid of. In contrast to cognitive evaluations, emotional reactions are sensitive to the

vividness of associated imagery, proximity in time, and a variety of other variables that play a minimal role in cognitive evaluations. Moreover, although emotional reactions are also sensitive to probability and outcome valence, the functional relationships are quite different from those for cognitive evaluations. As a result of these differences, people often experience a discrepancy between the fear they experience in connection with a particular risk and their cognitive evaluation of the threat posed by that risk (Loewenstein et al., 2001).

The feelings that become salient in a judgment or decision making process depend on characteristics of the individual and the task as well as the interaction between them. Individuals differ in the way they react affectively and in their tendency to rely on experiential thinking (Slovic et al., 2005).

All of the images in people's minds are tagged or marked to varying degrees with affect. An individual's "affect pool" contains all of the positive and negative markers associated (consciously or unconsciously) with the images. The intensity of the markers varies with the images (Slovic et al., 2005). People consult or "sense" the affect pool in the process of making judgments. Just as imaginability, memorability, and similarity serve as cues for probability judgments (e.g., the availability and representativeness heuristics), affect may serve as a cue for many important judgments (including probability judgments). Using an overall, readily available affective impression can be easier and more efficient than weighing the pros and cons of various reasons or retrieving relevant examples from memory, especially when the required judgment or decision is complex or mental resources are limited. This characterization of a mental shortcut has led researchers to label the use of affect a heuristic (Slovic et al., 2005).

There is also a possibility that emotional changes associated with *aging* may help to explain observed age-based differences in risk taking, and specifically adolescents' high risk-taking propensities. One popular explanation for adolescent risk taking is the so-called invulnerability hypothesis according to which adolescent risk taking stems from feelings of invulnerability. From a decision-making perspective, the invulnerability hypothesis implies that adolescents either do not consider some potentially harmful consequences of risky behavior or underestimate the likelihood of these consequences happening to them (Loewenstein et al., 2001).

Depending on the circumstances, moods and emotions can play useful as well as disruptive roles in decision making. (Shiv et al., 2005)

Conclusion

Although the effects have not always been maintained over periods longer than a year, behavior-change intervention research has produced considerable evidence that risky health behaviors can be changed and health outcomes improved. A variety of emerging intervention and dissemination approaches promise to increase the beneficial impact of the field's role in prevention by increasing the range of interventions, locations and systems for their implementation, and the levels of analysis on which they are based—from downstream individually based approaches to midstream organizational- and community-based interventions to upstream policy-level strategies. This latter development reflects a growing

and important balance between the traditional clinical focus on individual and small-group-based strategies typical of the field's early years and a newer population-based public health orientation. A well-developed scientific infrastructure supports these ongoing accomplishments and developments. This infrastructure takes the form of substantial and growing amounts of public and private research funding, recognition of this research area across a wide range of scientific fields and health professions, well-respected peer-reviewed outlets for related research, a large and capable pool of scientists, and a growing set of training programs for the future generation of health psychology researchers and practitioners of all sorts (Smith et al., 2004).

Integrating the main factors in the different models of health behaviour, it appears that people will decide to change their current risky behaviours and to adopt health-protective behaviours to the extent that (i) they perceive that they can suffer negative and severe health consequences if they keep behaving in a risky way, (ii) the protective behaviour is perceived as bringing them benefits, (iii) they are confident in their resources to control the potential difficulties and obstacles to carry out the protective behaviour, (iv) individuals are faced with social pressures to carry out the intended behaviour and are motivated to comply with these social pressures, (v) the behavioural information received concerning the risks of the current behaviour and of the benefits of the alternative behaviours activate positive affective responses, (vi) the behavioural changes suggested are consistent with individuals' other goals, values, and life projects, and, finally, (vii) the decision-making process could be influenced by the presence of internal or external stimuli that focus their attention on the risks they are facing and the ease of undertaking preventive actions (Bermudez, 1999).

It remains for dental health education researchers to fully develop and test the *strategies* framework, particularly regarding the durability of oral health behavior change. In addition, the identification of psychological variables, and the analysis of their association with different kinds of oral health behaviour, would permit the assessment of the individual's vulnerability and facilitate the identification of variables on which we should focus to improve the individual's dental health.

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Chapter 2

The Oral Preventive and Care Measures for Head and Neck Cancer

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Abstract

Oral assessment and care are essential prior to cancer treatments in order to decrease both incidence and severity of oral complications. Appropriate interventions have to be performed before the beginning of cancer treatments and/or during the treatment period. It is necessary to regularly perform the oral preventive and care measures by including appropriate counseling to the patients, so they are able to take care of themselves up to the desired outcome as well as the periodically follow up after the treatments of cancer. This review focuses on the oral preventive and care measures for head and neck cancers.

Introduction

Head and neck cancer (HNC) usually involves a multiplicity of diseases assembled which include malignancies of the oral cavity, pharynx, larynx, sinuses, salivary glands and skull base. Approximately 40% occur in the oral cavity involving the mucous membranes of the mouth, *i.e.* lip, the base of tongue, tongue, gum, floor of mouth and palate. About 25% arise in the larynx and 15% engage the pharynx which includes the malignancies of

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oropharynx, hypopharynx and nasopharynx. The rests are at the remaining sites; salivary glands, and *etc.* [1]. Other tumors that occur in this area such as those of the brain, thyroid and melanoma in general are not included in the term “head and neck cancer” [2]. HNC settles to be one of the most challenging diseases with accelerate incidence rate and high mortality. It is ranked as the eighth leading cause of cancer death worldwide [3]. The majority of HNC carry a poor prognosis due to late diagnoses that lead to poor survival and functional outcome, and despite the aggressive treatments, the recurrence of the diseases is frequent, particularly those with the malignancies at the nasopharyngeal region. They were regularly identified as a result of cervical lymph nodes metastasis, cranial nerve or the base of the skull involvement [4-7]. Approximately 70 % of the patients with nasopharynx carcinoma presented locally advanced stages of lesions [5]. Smoking (including smokeless tobacco) and alcohol drinking are the major risk factors, including some viral infections such as Human papillomavirus (HPV) [2, 5, 6, 8, 9]. In addition, Epstein-Barr virus (EBV) infection is strongly associated with nasopharyngeal malignancies which the population of southern China and Southeast Asia are at the high risk [2, 10, 11].

The treatment modalities designed are based upon the site, diagnosis, pathological result, clinical staging of the tumors; (Table 1) [12], and the physical condition of the patients. The standard treatments usually include radiation, chemotherapy, surgical resection or a combination of those. However, each intervention produces certain side effects either acute or late reactions; the severity varies on the type and extent of treatments, the host susceptibility as well as the site and dimension of tumor. Oral complications are the most common of the HNC therapies which may occur as early as the commencement of treatments and may be transient or cause permanent dysfunctions requiring a lifetime management. However, there are late complications that may not be observed until many years later after cancer treatments such as osteoradionecrosis (ORN) [13].

Chemotherapy designed for the HNC usually induces a number of adverse oral effects depending on the timing, doses and a variety of cytotoxic drugs regimen. The most common are cisplatin plus 5-fluorouracil which are now widely accepted as the standard in induction chemotherapy [14]. The combination use with other drugs such as docetaxel for more effective outcome without increase of toxicity has been reported [15-18]. However, the use of these medications induces myelosuppression, immunosuppression or direct cytotoxic effects to the host. These effects manifest themselves as mucositis, soft tissue ulceration, increase susceptibility to infections and bleeding [15]. Occasionally, osteonecrosis of the mandible associated with drug therapy bisphosphonates occurs particularly, in those with long-term used for the treatment of bone cancers and multiple myeloma [19, 20].

Radiotherapy usually covers a large area of head and neck which frequently involved the oral cavity and surrounding tissues in the radiation fields in order to provide an adequate dose to the tumor bed and regional lymph nodes. The irradiation doses needed for tumor control are often remarkably higher than the tolerance of the radiation sensitive structures such as the spinal cord, the optic nerves, the eyes, or the salivary glands in the treatment of HNC. Particularly with standard radiation techniques, even the optimum therapeutic dose still can induce a number of side effects, which occur in a different pattern according to the anatomy complex formed by many different tissues in the area.

Table 1. The TNM *classification of nasopharyngeal carcinoma (NPC) staging according to the American Joint Committee on Cancer (AJCC) [12]

AJCC stage groupings of NPC							
Stage 0	Stage I	Stage IIA	Stage IIB	Stage III	Stage IVA	Stage IVB	Stage IVC
Tis, N0, M0	T1, N0, M0	T2a, N0, M0	T1, N1, M0 T2, N1, M0 T2a, N1, M0 T2b, N0, M0 T2b, N1, M0	T1, N2, M0 T2a, N2, M0 T2b, N2, M0 T3, N0, M0 T3, N1, M0 T3, N2, M0	T4, N0, M0 T4, N1, M0 T4, N2, M0	any T, N3, M0	any T, any N, M1
T = (primary tumor stage) Tx = primary tumor cannot be assessed T0 = no evidence of primary tumor Tis = carcinoma in situ T1 = tumor confined to the nasopharynx T2 = tumor extends to soft tissues T2a = tumor extends to the oropharynx and/or nasal cavity without parapharyngeal extension T2b = any tumor with parapharyngeal extension T3 = tumor invades bony structures and/or paranasal sinuses T4 = tumor with intracranial extension and/or involvement of cranial nerves, infratemporal fossa, hypopharynx, orbits, or masticator space N = (regional lymph nodes) Nx = regional lymph nodes cannot be assessed N0 = no regional lymph nodes metastasis N1 = unilateral metastasis in lymph node(s), ≤ 6 cm in dimension, above supraclavicular fossa N2 = bilateral metastasis in lymph node(s), ≤ 6 cm in dimension, above supraclavicular fossa N3 = metastasis in lymph node(s), > 6 cm in dimension, and/or to supraclavicular fossa N3a = metastasis in lymph node(s), > 6 cm in dimension N3b = metastasis in lymph node(s), extension to supraclavicular fossa M = (distant metastasis) Mx = distant metastasis cannot be assessed M0 = no distant metastasis M1 = distant metastasis							

The most common and distressing adverse effects of radiation therapy are oral mucositis and xerostomia resulting from salivary gland damage, which may predispose to infections and caries, disturbance of speech and swallowing [21, 22]. The patients may not complete the prescribed cancer therapy due to the toxicity effects. The use of radiation therapy techniques that spare normal tissues, such as intensity-modulated radiotherapy (IMRT), helps minimize the stomatotoxic effects by sparing the surrounding normal tissue exposed to radiation. The use of IMRT has gained its popularity in the treatment of HNC. IMRT delivers the desired amount of high dose radiation to the tumor target and significantly reduces the amount of radiation dose to

the normal tissues. It conveniently enhances the patient's therapy fulfillment as the toxicity associated with radiation therapy is diminished. However, there are still a number of side effects induced during or following IMRT [23].

Surgical resections of tumors generally comprise a large amount of the normal tissue to obtain tumor-free margins. Particularly, in the region of the oropharynx, surgical procedures endure significant morbidity including acute post-traumatic neuropathic pain and other that associated with muscular fibrosis and scar formation such as dysphagia, trismus and speech dysfunction. These depend on the extension of organ/ tissues involved and tissue defects. In addition, esthetic problem, which is one of the factors affects functional social status of the patients is common, despite advanced surgical reconstruction [6, 24-26].

When the combination of cancer treatments were done (e.g. a combination of chemoradiation, followed by adjuvant chemotherapy for the treatment of advanced malignancies, in order to improve the local control and survival), the high doses of radiation concurrent with chemotherapy enhanced more radiation effect. The severity of treatment complications as the cytotoxicity, the extent of pain and discomfort increase and significantly distress the patients' quality of life. The harsh results may affect the competency of cancer therapy, and may lead to an interruption or halt the sequences of treatments [6, 27]. The unscheduled hospitalization of the patients due to treatment-related toxic effects is common [23, 28]. The most frequent causes are due to mucositis, dehydration and electrolyte imbalance, sepsis, febrile neutropenia, pneumonia, and malnutrition [23, 27]. Approximately one third of the patients did not complete the prescribed therapy due to toxicity [27].

The optimum oral health plays an important role for the patients with head and neck cancer. Since the oral tissues are highly susceptible to the cancer treatments, the aggregated existing poor oral health as well as traumatic injuries to the oral soft tissues may create more severe complications, life threatening during cancer therapy when the patients become immunocompromised. Infections of dental or periodontal origin are considered as a serious risk to head and neck cancer since these may turn into causes of severe infections and systemic dissemination [29]. In contrast, good oral hygiene and good dental status facilitate prevention and decrease incidence and severity of the oral complications. Since the patients must attain the healthy oral status before the beginning of cancer treatments, the consultation with the dental professional for the oral preventive care measures has been highly recommended. The necessary dental procedures should be completed before the initiation of cancer treatment. In addition, the continuity of oral health care measures must be ensured during and after the cancer treatments. This review focuses on the oral preventive and care measures to provide healthy oral condition and improve the quality of life for the head and neck cancer patients.

There are four major parts of oral preventive and care measures for head and neck cancer; 1) Oral assessments and management of dental problems, 2) Oral preventive and counseling prior to cancer treatment, 3) Management of oral complications from cancer treatment and 4) Periodically recall examination.

1. Oral Assessment and Management of Dental Problems

It is essential for the patients to achieve a good oral health before the beginning of cancer treatments. Following to the diagnosis and the proposal of treatment modalities for the malignancies, oral assessment should be performed as early as possible. Particularly, when radiotherapy is performed the patients may require comprehensive dental treatments and possibly invasive dental procedures, *i.e.* tooth extraction and alveolectomy that need sufficient time for adequate wound healing [30]. Besides, the majority of head and neck patients need oral care before cancer therapy for the reasons of poor oral hygiene and noncompliance of regular dental care [29, 31-37].

The objectives of oral assessment and dental treatments are to evaluate the existing oral status of the patients and maintain the healthy oral conditions. The rationale is to eradicate the possible causes of infections and potential traumatic injuries to the oral soft tissues for the prevention of unwanted oral complications [28, 29, 31].

The oral assessment usually includes complete oral examination and the radiographic survey. A careful assessment of the following should be included:

Existing dental and periodontal diseases: Dental caries, improper conditions of fillings, sharp edges teeth, impacted teeth, and non opposed teeth should be carefully evaluated especially those which will be causes of traumatic injury to the oral mucosa. Complete dental and periodontal charting should be done to set up the baseline information.

Oral soft tissue: Hard and soft palate, labial and buccal mucosa as well as the tongue should be carefully evaluated especially for those patients who wear dentures; the soft tissues related to dentures should be carefully assessed.

Condition of dental prostheses: The proper fitting and condition of removable dentures should be assessed; if there are any problems, they should be adjusted, relined or replaced to prevent the possibly of traumatic injury to the ridges. Fixed prostheses such as implants, crown and bridge should be well retained and hygienic.

Saliva flow: Stimulated whole saliva and unstimulated saliva of the patients should also be assessed as the baseline evaluation particularly, in the radiated patients. There are many noninvasive procedures to collect the saliva; the collection can be either unstimulated (resting saliva) or stimulated (*e.g.*, gustatory stimulation with citric acid or by chewing). Saliva production by all of the glands collectively can be measured by drooling, spitting, drainage, or weighing cotton rolls inserted into the mouth, the most common method being by direct spitting into a premeasured cup or tube. However, before collecting the saliva, the patients should be instructed to refrain from eating, drinking or toothbrushing for an hour. During collections, they should be seated and orofacial movements that influence the salivary flow such as sucking or swallowing for the entire procedure minimized.

The procedure collecting the unstimulated saliva includes; instruct the patients to empty the mouth first then to accumulate saliva in the floor of mouth for 60 seconds without swallowing, and to spit into a tube. Repeat this procedure four more times for a total collection time of five minutes.

Collection of stimulated whole saliva is done by using saliva stimulants including chewing gum base, paraffin wax, rubber bands, sucking on a sugar free lemon flavored candy and the use of citric acid. Let the patients suck on sugar free lemon flavored candy or chewing gum. Then collect the saliva for five minutes with the same procedure as collecting unstimulated saliva. Or use a cotton bud soaked with 2% citrate solution applied to the bilateral of the tongue for several times then let the patient spit the retained citrate solution and start to collect the saliva as above [31, 32].

Measurement of maximum mouth opening: Inter-arch or inter-incisal distance should be measured for baseline measurement. Occasionally limited jaw movement and pain resembling temporomandibular disorder (TMD) may develop as signs and symptoms of nasopharyngeal carcinoma (NPC) penetrating into masticatory muscles and/or the temporomandibular joint. Thus it is essential for the dental professional to recognize other key symptoms enable to differentiate diagnosis between them, and avoid delay in diagnosis and treatment of NPC such as neck masses, nasal obstruction, unilateral hearing deficit and epistaxis [4, 38].

Patients who are at risk of trismus should be instructed to do home exercises to maintain maximum mouth opening and jaw mobility early at the beginning of radiotherapy. Frequent measurement should be performed to ensure the maintenance of maximum mouth opening. A careful assessment should be done since the prevention is preferred rather than the treatment [39, 40].

Radiographic survey: Both dentate and edentate patients should have radiographic examination including panoramic, selected periapicals and bitewings. Even for edentate patients, the evaluation of retained root, residual cyst and any pathological lesions should be done.

Oral hygiene assessment: the extent of plaque and calculus deposit should be evaluated, the assessment should include the patient's self awareness of their dental health, their motivation and ability to perform oral hygiene procedures.

The Recommended Dental Procedures before Cancer Treatments

The treatments vary from individual to individual. If radiation is the therapeutic modality, the knowledge of radiation dose, field of radiation and tumor prognosis are necessary for the treatment plan. In addition, the prevention of ORN should be seriously considered in the treatment plan. A careful, pre-irradiation assessment should be attempted to identify the main factors that possibly increase the risk for ORN. Some treatment procedures can be performed before the beginning of radiotherapy in order to control or eliminate those factors as many as possible [41, 42]; therefore, the consideration of more aggressive dental managements in patients with poor oral hygiene, evidence of past periodontal diseases and non-compliance or limited previous dental care is recommended [35, 36].

In conclusion the treatment planning prior to radiation should be based upon a full dental, periodontal and radiographic assessment and treatment to establish an optimal dentition that the patient may maintain for their lifetime.

Regular dental prophylaxis is recommended since all teeth should be clean and in good hygiene. Sealant is recommended on all exposed tooth surfaces in the young [43].

Periodontal diseases should be treated, including calculus removal root planning, and soft tissue curettage. The emphasis of daily plaque control is necessary in order to eliminate the local causes of the diseases. Meticulous care must be taken before, during, and after radiation treatment. However, the periodontal surgery is not recommended because of prolonged healing; a scrupulous oral hygiene is necessary for a good final result [44, 45].

Dental caries should be treated; teeth restorations/fillings should be up to an acceptable level. All irritating factors which may traumatize the oral mucosa such as sharp edge teeth, and rough filling, should be smoothed and polished. Inadequate filling, e.g. broken or leaking should be repaired and replaced as well. Endodontic treatment can be done in caries exposed to the pulp with proper performance [44].

Dental prostheses should be adjusted and repaired if ill-fitting or broken for either both full and removable dentures (prevention of trauma to the ridges). All fixed prostheses including implants, crown and bridges should be in good condition and hygienic [34, 39, 46]. However, orthodontic appliances should be removed and the treatment should be postponed for 1 year after the completion of cancer therapy [43].

Tooth extraction may be required in order to reduce the overall risk of osteoradionecrosis. The criteria used for extractions before radiotherapy have been a controversial issue for a long time and are subject to clinical experiences and judgment of the dental team [39, 44]. However, tooth extractions are recommended in the following circumstances; all teeth in direct association with an intra oral tumor or in the high-dose radiation field, those with a questionable prognosis [36, 41, 42], non-restorable, advanced caries lesions with questionable pulpal status or pulpal involvement tooth with extensive periodical lesions [45, 47]. Moderate to advanced periodontal disease (pocket depth in excess of 5 mm), especially with advanced bone loss and mobility or furcation involvement should be extracted [44, 45]. Retained root or residual root tips not fully covered by alveolar bone or showing radiolucency, impacted or incompletely erupted teeth, non-opposed teeth, particularly third molars that are not fully covered or that are in contact with the oral environment and compromised hygiene should be removed.

Primary teeth with any risk of pulpal involvement and those that will exfoliate within 3 months should be removed. The less motivated the patient, the more aggressive one should be in extracting teeth prior to radiotherapy [35, 36].

If tooth extraction is unavoidable, antibiotics coverage before and after is recommended. A non-traumatic approach and good surgical technique with primary closure are suggested for the extraction [36]. The bone at the wound margin should be trimmed evenly, loose bone spicules and sharp projections must be removed, and the bone must be contoured so that closure at the extraction site is possible. Alveolectomy should be done to ensure smooth alveolar ridge and prepare for construction of denture after cancer treatment.

Pre-irradiation extractions performed at the suitable time do not significantly increase the overall risk of ORN [48]. Optimal post surgical time required for adequate healing prior radiotherapy is within 2 to 3 weeks. However, a minor risk for the development of ORN was observed for a post surgical time interval of 14 days between extraction and initiation of radiation therapy, while no risk was observed at time interval of 21 days or more [49]. The

time between the diagnosis of the tumor and the start of the radiotherapy should be kept as short as possible in a case that requires the highest probability of cancer cure [39].

Nonetheless, if the patients show a history of good oral hygiene and compliance with routine and continuing dental professional visit, asymptomatic teeth such as chronic root furcation involvement without acute infection or tooth mobility, teeth with asymptomatic and well localized periapical lesions can be exempt from extraction as well as complete bony impaction [47, 50, 51]. The emphasis of oral assessment and dental procedures before cancer treatment especially radiotherapy, is shown on Table 2.

Table 2. The Oral Assessment and Dental Procedures for Head and Neck Cancer Before Radiotherapy

Oral assessment	Existing conditions	Recommended treatment	Indication for prophylaxis extraction/surgery
Tooth conditions	dental caries caries with pulpal involved faulty restorations sharp edge tooth	filling endodontics treatment refilling/polishing smoothed/reduce sharpness	tooth with a questionable prognosis teeth in the high-dose radiation field all teeth in direct association with an intra oral tumor non-restorable caries/tooth retained root tooth with extensive periapical lesions non-opposed and are difficult to for prosthetic treatment tooth with compromised hygiene/unable to clean /easily food impacted partial impaction or partially eruption third molar
Periodontium	dental plaque/calculus gingivitis periodontal diseases	prophylaxis, scaling curette, root planning	severe periodontitis pocket $\geq$ 5-6 mm needed periodontal surgery periodontitis with the furcation involvement
Oral soft tissues			
tongue, hard and soft palate	unhygienic/lesion	as needed	all teeth in direct association with an intra oral tumor

Oral assessment	Existing conditions	Recommended treatment	Indication for prophylaxis extraction/surgery
labial and buccal mucosa		gentle brush/ wipe with wet gauze pad use tongue scraper	
Dental prostheses			
removable prostheses	broken/loose/unhygienic	adjusted/reline/change	retained root, symptomatic cyst, bone exostosis under denture improper crown and bridge and dental implants
fixed prostheses			with poor maintenance of hygiene and excessive bone destruction peri-abutment/peri-implants
-crown and bridge	Unhygienic/loose	as needed	
-implants			
Saliva flow	resting flow rate stimulated flow rate	baseline information	
Mouth opening	Maximum length measured	Frequent practice maximum opening	
Radiographic survey			
orthopan/panoramic	condition of tooth/ supportive alveolar bone/jaw		
bite wing			
selected periapical			
Children	unhygienic/caries /lesion gingivitis/periodontitis	same as adult	all primary teeth risk of pulpal involvement those that will exfoliate within 3 months
Orthodontic appliances	fixed appliances	removed/wait 1 yr after RT	

2. Oral Prevention and Counseling Prior to Cancer Treatment

The rationale of preventive counseling is to attain a high cooperation of the patients, particularly a continuous, meticulous oral hygiene and compliance of the treatment plan for the prevention of possible treatment complications such as infections, radiation caries, and ORN. Thus, the patients must be informed and understand the rationale of the oral hygiene

program as well as the potential effects of cancer therapy both from radiotherapy and chemotherapy.

Preventive program: The program usually includes primary preventive measures, such as appropriate nutritional intake, effective oral hygiene practices, and the use of topical chemotherapeutic agents and early detection of oral lesions. This is important prior to cancer treatment since the severity of oral complications from cancer treatment can be reduced significantly when an aggressive approach to stabilizing oral health is performed [32, 43, 52].

Dietary counseling: A sufficient intake of diet is important; however, the cariogenic diet intake should be seriously considered since it can lead to dental caries when combined with poor oral hygiene. The patients may require multiple extractions and alveolectomy (the ridge preparation for future dentures). The procedures performed may cause pain and eating difficulties that lead to minimized diet intake. For prevention of weight loss, the counseling of diet modification is necessary and the use of gastric tubes for nutritional management may become necessary. Patient's weight and nutritional input should be assessed at the beginning of treatment and regularly on a weekly base throughout cancer treatment [53]. Weight loss is a considerable problem in most patients, even with the regular use of gastric tubes for nutritional management. In addition, approximately 70% of the patients observed required gastrostomy tube (G-tube) placement before cancer treatments [28].

Effective oral hygiene practices: These practices usually involve the mechanical plaque removal which usually includes toothbrushing, interproximal cleaning and the use of other cleaning devices. Frequent daily tooth-brushing, after meals and before bedtime is recommended. Flossing or cleaning (with other devices) between proximal of the teeth should be done at least once a day, preferably before bed time. Oral soft tissues should be cleaned regularly with the use of cotton tips, sponge on sticks, or wet gauze, for wiping the area of buccal mucosa, palate, and tongue. Even in edentate patients, the alveolar ridge should be cleaned regularly with soft brush or wiped with wet gauze. When toothbrush and dental floss are not appropriate and can be traumatic to patients with neutropenia, these patients should be encouraged to have their mouth thoroughly cleaned at all times for prevention and to lessen oral complications [45].

Topical chemotherapeutic agents: They are used for dental preventive program *e.g.* topical fluoride and prophylactic rinses.

The rationale of the using fluoride is to make the tooth surfaces less susceptible to the decay, to inhibit demineralization, to enhance remineralization and the enzyme inhibitor in order to reduce the acidity of the dental plaque. A combination of increased fluoride concentration on the tooth surface and the effect of fluoride on the plaque and on the microflora in the oral cavity can reduce dental caries. The use of topical fluoride is essential for dental caries prevention before the treatment of cancer, especially those that require radiotherapy should use it persistently throughout the treatment and afterwards for lifetime [37].

It is highly recommended to apply a 10,000 ppm fluoride gel (1% neutral sodium fluoride gel or 0.4% stannous fluoride gel with custom built fluoride tray for each patient). The procedures include, brushing the teeth thoroughly, then apply 1% neutral sodium fluoride gel or 0.4% stannous fluoride gel to the teeth surfaces for 5 minutes with the individual tray once or twice a day [37, 43]. Patients who have problem holding fluoride tray in the mouth for a

long time should brush with fluoride gel for 2 to 3 minutes or with a dentifrice with a high concentration of fluoride (5.000 ppm) [43, 54]. However, a close follow-up is necessary.

The use of prophylactic rinses is potentially beneficial for controlling dental plaque level, gingivitis, caries risk, and oropharyngeal candidiasis [43, 55, 56]. The most common recommendation is chlorhexidine, which is a broad-spectrum topical antiseptic with considerable oropharyngeal substantivity; the effect is up to 12 hours of contact time after topical application [57]. It is recommended for the reduction of oral microorganisms such as mutans streptococci, and lactobacilli [37]. The use of chlorhexidine mouthwash and fluoride gel twice daily for at least one week prior to the beginning of cancer treatment will help the treatment of gingival disease in combination with improved oral hygiene practices [58]. The emphasis of oral preventive counseling prior to cancer treatment is shown on Table 3.

Table 3. The Oral Preventive Measures for Head and Neck Cancer Before Radiation

Before radiation	recommended interventions	comments/expectations
Counseling	Inform -rationale of the oral hygiene program -potential effects of cancer therapy (radiation field/dose, tumor prognosis) Oral/dental treatment plan Oral assessment/dental treatments	a high cooperation of the patients compliance of the treatment plan continuous self-meticulous oral hygiene
Effective oral hygiene practices	Mechanical plaque removal -tooth brushing -interproximal cleaning -soft tissues cleaning -use of other cleaning devices.	plaque control remove of food debris
Use of topical chemotherapeutic agents	Topical fluoride -gel/custom fluoride tray -dentifrice -rinse Chlorhexidine In children sealants on all exposed tooth systemic fluoride	caries control control plaque levels gingivitis reduced caries risk oropharyngeal candidiasis Caries control Caries control
Dietary control	Avoid cariogenic food Consider diet modification Adequate intake of diet	Caries control Those with multiple tooth extraction Regular weight observed

3. Management of Oral Complications

There is a variety of side effects of chemotherapy and radiotherapy, either acute or late effects. Almost all patients who underwent cancer treatments experienced oropharyngeal complications during and after therapy [56, 59].

The Oral Complications during Cancer Treatment

During cancer therapy of HNC, mucositis is the most common complication resulting from acute toxicity. The hematological toxicity is also important since neutropenia and anemia can possibly lead to sepsis and death [56, 59].

Oral Mucositis (OM)

Oral mucositis is a common complication of cancer treatments from both chemotherapy and radiotherapy. It is the dose-limiting toxicity of treatment modalities like accelerated fractionation and hyperfractionated radiotherapy and of the interventions that combine chemotherapy and radiotherapy. OM is characterized by mucosal erythematous, erosive and ulcerative lesions which may be covered by a white pseudomembrane (Figure 1) [56].

It is the most debilitating among those complications of cancers therapies, which often has many consequences including pain and discomfort that lead to compromised nutritional intake as well as problems of communication and sleep. In addition, the requirement of strong systemic analgesics and enteral nutritional support is common in order to maintain dose intensity throughout the entire radiation/chemotherapy regimen.

The incidence rate of mucositis is approximately 55-86% [60, 61, 62]. Oral and gastrointestinal (GI) mucositis can affect up to 100% of the patients undergoing high-dose chemotherapy and hematopoietic stem cell transplantation, as well as 80% of patients with malignancies of the head and neck receiving radiotherapy, and a wide range of patients receiving chemotherapy [63]. However, 100% of the patients receiving high-dose head and neck radiation according to the World Health Organization (WHO) have severe oral mucositis (grade 3 or 4). The combined use of chemoradiotherapy accelerates frequency, severity and duration of mucositis which may cause long term damage to the gastrointestinal system. In severe cases of mucositis, dysphagia and aspiration can be anticipated.

The clinical signs of chemotherapy-induced mucositis occur approximately 6-10 days after treatment, although the biological tissue changes begin instantly [62]. It is generally limited to non-keratinized mucosa and most commonly involves the soft palate, ventrum of tongue/floor of the mouth, and buccal mucosa. Without infections it will spontaneously heal within 2 to 4 weeks [33, 43, 56, 59, 62, 64]. OM caused by radiotherapy is a function of cumulative tissue dose and usually begins at a dose of about 15 Grays (Gy) to 20 Gy of standard or conventional fractionated radiation therapy. This fractionated therapy has an average dosage of 2 Gy per fraction daily for 5 days a week and usually lasts for 6 to 8 weeks [65].



Figure 1. Erythema and ulcerative of the buccal mucosa (A), erythema of dorsum of the tongue (B), ulcer at the lateral border of the tongue (C) were demonstrated after radiation.

Initiation phase of mucositis begins with radiation induced injuries to submucosal tissues that enhance the up-regulation of a series of early-response gene. Changes are observed in the endothelium, connective tissue, and extracellular/matrix and also induced free radical released from tissue injury. The released free radicals up-regulate cytokine associated transcription factors, especially nuclear factor-kappa B (NF- κ B), which stimulates transcription of cytokine associated genes and leads to inflammatory cytokines production [66]. These inflammatory responses result in tissue destruction and cell death (necrosis and apoptosis). Tissues healing and repair generally occur at the same time depending on the balance between the tissues destruction and healing process which will dictate the outcome of tissue healing with complete resolution [67]. However, during therapy, the continuous radiation induces persistent tissues injuries that cause outpace of the healing processes. Around the second week of radiation, ulcerative mucositis or the ulcerative phase can be noticed [56].

Even though the stomatotoxic effects of cancer therapy can be reduced with IMRT, a variety degree of mucositis was still observed in all patients following IMRT, and some of them were hospitalized because of mucositis [23]

Spontaneous healing can be anticipated within 3 weeks after the end of the treatment; however, the use of high dose radiotherapy and smoking delay the healing of mucositis [33, 56].

The severity of mucositis, either induced by radiation or by chemotherapy can be classified based on the clinical features and functional impairments (corresponding dietary limitations). According to National Cancer Institute (NCI) Common Terminology Criteria for Adverse Events Version 3.0 (CTCAE) [68], mucositis can be graded as presented on Table 4.

In addition, the oral mucosa usually plays an important role as mechanical barrier preventing the invasion of a variety of microorganisms, originally present in the mouth locally or systemically and also prevents the absorption of toxins produced by such microbes. The loss of host barrier due to tissue injuries and ulcers additionally increases the extent of mucosal injuries which, in turn, can increase the susceptibility for systemic infection [30].

The major concern is that, when the patients are immuno-compromised, the presence of neutropenia precipitates the patient's risk of infections. Because of the presence of ulcerative mucositis teeming with microorganisms, it can be a major primary condition predisposing to bacteremia and sepsis. Besides, concurrent neutropenia might aggravate the situation and delay recovery of mucositis [32, 34, 52, 69, 70].

Management of Mucositis: The main objectives for treatment of mucositis usually comprise of elimination of mucosal-irritating factors, maintenance of good oral hygiene, prevention and treatment of infections (will be discussed later in this chapter). It regularly includes symptomatic treatments of oral cavity and lips, mucosal pain and inflammation. Management of oral mucositis is usually by palliative and conservative treatments [32, 34, 70].

Table 4. The classification of oral mucositis severity either induced by radiation or chemotherapy according to the clinical features and functional impairments (corresponding dietary limitations) [68]

Severity of Oral Mucositis	Clinical features and functional/symptomatic impairments (consequent dietary limitations).
Grade 1:	Erythema of the mucosa Minimal Symptoms, normal diet
Grade 2:	Patchy ulcerations or pseudomembranes Symptomatic but can eat and swallow modified diet
Grade 3:	Confluent ulcerations or pseudomembranes; bleeding with minor trauma Symptomatic and unable to adequately alimentary or hydrate orally
Grade 4:	Tissue necrosis; significant spontaneous bleeding, life-threatening consequences Symptoms associated with life-threatening
Grade 5:	Death

Elimination of mucosal-irritating factors: Assessment of oral cavity, dental examinations should be continued throughout active cancer treatments, a close follow up is recommended [63, 71]. During mucositis, some unexpected dental related problems such as broken fillings, denture problems related to dry mouth may occur. Approximately 50% of the patients observed were not very satisfied with their prostheses, especially for the mandible, even when wearing them only a few hours per day, [72].

Basic oral care/maintenance of good oral hygiene: The purpose of basic oral care is mainly to reduce the impact of the oral microbial flora, diminish cancer therapy-related symptoms of pain and bleeding, and prevent soft tissue infections that may have systemic sequelae. In addition, maintenance of good oral hygiene will reduce the risk of dental complications, including caries and gingivitis. For these reasons, basic oral care is an important component of care of the patient with cancer [73]. Nonetheless, it is important to recognize that although there is no sufficient scientific evidence to provide a guideline for basic oral care, its importance in maintaining mucosal health, integrity, and function is generally accepted. Preventive oral care procedures should be part of routine supportive care along with therapeutic oral care procedures when mucositis develops [63, 71].

Oral care procedures should be multidisciplinary, including an effort of mucositis prevention and management. It should be feasible, easy to adhere to, and comprehensive as far as patient's education regarding mucositis and oral care. The staff education in the use of such protocols is also necessary for the reduction of severity of oral mucositis [63, 71].

Maintenance of oral hygiene is the most important measure in reducing the incidence or severity of mucositis [74]. Since good oral hygiene minimizes the breakdown of the mucosa and promotes healing, thus, it reduces infection and the risk of bacteremia [55, 75]. Improved oral conditions enhances oral comfort; the patients who received the oral care instructions were observed to comply better with their routine oral hygiene and were well prepared to handle their symptoms [76, 78].

In children, there were some oral care protocols developed in order to reduce the incidence and severity associated to oral pain. The daily combination of tooth brushing, chlorhexidine rinse and saline resulted in a 38% reduction in incidence and a significant reduction in severity and associated oral pain [52]. A daily preventive protocol in those with leukemia that included plaque removal, chlorhexidine rinse, iodopovidone, and nystatin rendered a significant decrease in moderate mucositis and candidiasis and improved oral hygiene as well [79]. It was observed that toothbrushing alone brought a reduction of the number of oral lesions in patients receiving cancer chemotherapy [80]. Regular, systematic, oral care hygiene with brushing, flossing, bland rinses, and moisturizers using a standardized oral care protocol should be implemented for all patients. An interdisciplinary approach to oral care (nurse, physician, dentist, dental hygienist, dietician, pharmacist, and others as relevant) will provide the most comprehensive means of providing supportive care.

Normal daily toothbrushing with a soft toothbrush after meals and before bedtime is recommended. Flossing without gingival trauma should be continued in patients with skill unless contraindicated by thrombocytopenia and neutropenia ($< 20,000$ to $50,000$ platelets/mm³ or < 500 to $1,000$ neutrophils/mm³) [81]. The use of ultra soft toothbrush or sponge on stick is recommended in the vulnerable patients. Besides that, sponge on stick may be used for cleaning the mucosa of alveolar ridge, palate and tongue [34, 39, 43, 49, 54].

The use of regular toothpaste may be too strong and irritate the oral mucosa; in this case, it should be replaced with mild flavored toothpastes with fluoride. If all toothpastes irritate the patients should be encouraged to brush just with salt water by using 1 teaspoon of salt added to 4 cups of water [54].

If toothbrushing causes pain in the mouth, the patients can wipe their oral mucosa and teeth gently with gauze soaked in salted water to remove food particles or use cotton bud or gauze soaked in aqueous base chlorhexidine; oral tissues should be swabbed 3 to 4 times daily. Sponges are softer than cotton buds and cause less bleeding and pain when applied to the already inflamed mucosa [33, 34, 43].

However the use of foam brush, cotton buds or sponges on sticks cannot adequately remove dental plaque, and thus, they cannot be recommended for plaque control or caries prevention since it is not comparable to regular toothbrushing [63, 71]. Routine care of oral hygiene by toothbrushing and flossing should be resumed as soon as possible when the pain is subsided. Discontinuation of routine oral hygiene can increase risk of local and systemic infection. Plaque accumulation and gingivitis may cause more problems than the risk of hemorrhage from toothbrushing and flossing. The patients should be encouraged to keep their mouths very clean as long as oral self care remains atraumatic [54].

Palliative care to promote oral comfort: The regular assessment of oral pain using valid self-reported form (questionnaires) is essential. Management of mucositis and acute oral pain is an important component of patient care. The promotion of oral comfort using systemic/topical anesthetics or other agents should be considered, as well as the prevention and treatment of infections. In general, pain management for mucositis generally follows the existing clinical practice guidelines, such as those publicized by the World Health Organization and the Society for Health Care Research and Quality for Managing Acute Pain [82, 83].

The use of systemic analgesics for the systemic pain relievers: The guidelines accepted the use of nonopioids, opioids, adjuvant medications, and assessment tools. Depending on the individual patient population, numerous routes may be considered, including oral, transmucosal (oral and rectal), and transdermal routes, as well as various intravenous approaches. Morphine (intravascular morphine sulfate) is recommended for patient-controlled analgesia (PCA) as the drug of choice for the treatment of oral mucositis pain in patients undergoing hematopoietic stem cell transplantation (HSCT). However, there is little evidence to recommend its use in other patients and settings [63]. Although other opiates may achieve similar pain control, morphine appears to require relatively lower drug doses and may be tolerated better [63]. However, the use of NSAIDs and aspirin-type analgesics should be avoided in cases of bleeding risk in chemotherapy induced mucositis [43, 54].

The use of topical anesthetics/analgesics: Topical anesthetics are recommended to provide short-term pain relief for oral mucositis on an empiric basis. A variety of topical preparations have been in widespread use for the treatment of mucositis and symptomatic relief of pain. The most common ingredients include viscous lidocaine, benzocaine, milk of magnesia, kaolin, pectin, chlorhexidine, and diphenhydramine [63].

A topical analgesic that can be considered is benzydamine, a topical nonsteroidal drug which has anti-inflammatory, analgesic, anesthetic, and antimicrobial properties. The results of a large, multicenter, double-blinded, randomized trial demonstrated that 0.15%

benzydamine oral rinse improved the ulcer-free rate and decreased the incidence of ulceration and erythema and pain associated with mucositis [84]. The study also demonstrated a delay in the need for analgesics in patients who were treated with benzydamine which based on cumulative radiation doses of 50 grays (Gy). The efficacy of the drug with higher doses or with combination chemotherapy was not established as well as in the patients who received accelerated radiation, benzydamine was not effective [84]. The use of 0.15% benzydamine oral rinse (1.5 mg/ml benzydamine) is recommended (rinsing 15 ml for 2 minutes , 4-8 times daily before and during radiotherapy , and 2 weeks after completion of radiotherapy). If burning or stinging occurred, dilution of the rinse with water at 1:1, or 1:2 was allowed [84].

Oral rinses: The patients should be encouraged to rinse their mouths frequently. Rinsing helps remove food particles and bacteria from the mouth and prevents crusting of sores in the mouth [44]. Regular oral rinses such as isotonic saline or sodium bicarbonate solution is suggested (Use 8 to 12 ml of rinse, hold and expectorate; repeat every 2 to 4 hours as needed for pain [54, 69]).

Chlorhexidine is not recommended to prevent or treat oral mucositis in HNC patients who are undergoing radiotherapy since there were no evidences supporting such treatment [63]. Besides, chlorhexidine mouthwash may contain alcohol, which can irritate the oral mucosa. The potential benefits of prophylactic rinsing with chlorhexidine are to control plaque levels, gingivitis, reduce caries risk, and oropharyngeal candidiasis rather than any effect on oral mucositis [63].

During mucositis, the repeated use of mouthwash containing alcohol, hydrogen peroxide and some acidic non prescription oral preparations for preventive oral hygiene is not recommended, since they can cause erosion and tooth sensitivity or damage the mucosa and delay wound healing [34, 54].

Diet modification: Patient's weight and nutritional input should be assessed regularly throughout cancer treatment. Adequate nutrition intake is essential. They should be advised to take a soft bland diet and drink a high volume of water to help preserve the moistness of tissue and the body fluid balance. Non acidic fruits such as banana, melon, ripe sweet mango, ripe peach and pear cause no damage to fragile mucosa. Frozen yogurt, or ice cream may be especially soothing. Certain foods may irritate or harm the fragile mucosa, especially in patients with existing mucosal ulcer, *i.e.*, hard, abrasive, salty, spices food, and acidic fruit and juices. Hot drinks may also exacerbate the oral mucosa; besides, coffee and tea, being diuretics may worsen dry mouth and should be avoided as well as drinking alcohol and smoking tobacco [54]. Soda or carbonated fizzy drinks with a low pH usually between 2.5 to 3.8, which may contribute to tooth sensitivity and irritation of the oral mucosa, should be avoided [2, 34, 54]. Enteral feeding should be initiated when the patients lose more than 5 kg or 5-10% of the body weight or consume less than 50% of daily nutritional requirements [53]. The patients with removable prostheses; dentures should be restricted to meal times only and should be left out when sleeping. The use of denture should be discontinued when trauma to the mucosa appears, and during ulcerative mucositis. Appropriate cleaning of dentures should be done after every meal and when they are not worn, they should be soaked in an antimicrobial solution [43, 54, 85].

Some treatment interventions are recommended for the prevention of oral mucositis according to Clinical Practice Guideline (CPG) 2007 [71]. Cryotherapy is recommended in

prevention of oral mucositis associated with short half-life stomatotoxic 5-FU chemotherapy. In approximately 50% of patients who received oral cryotherapy, a reduction of mucositis was observed [84, 86]. The patients were encouraged to swish ice chips in their mouths for a total of 30 minutes, beginning 5 minutes before the administration of intravenous infusion. The assumption is that ice chips would cause cooling of the oral cavity, induce local vasoconstriction and decrease blood flow to the oral mucosa during the peak serum concentrations, thus helping reducing chemotherapeutic drug exposure and also the risk of mucositis. The extension of time for oral cryotherapy did not provide additional advantage [87]. However, in patients who received continuous infusions of 5-FU or those undergoing administration of agents such as methotrexate, doxorubicin, or other long serum half-life drugs, the prevention of oral mucositis by oral cryotherapy is practically not expected [63]. This therapy's low cost and its minimal toxicity justify its use [63].

Keratinocyte growth factor-1 (palifermin); with the dose of 40 lg/kg/day for 3 days has been beneficial in the prevention of oral mucositis in patients receiving bolus 5-FU plus leucovorin [63]. The use of midline radiation blocks and three-dimensional radiation treatment to reduce mucosal injury is recommended for the prevention of mucositis from radiotherapy [71]. It has been shown that oral mucosal injury secondary to radiotherapy may be reduced significantly by the use of midline radiation blocks [88]. The effects of altering the delivery of cytotoxic therapy have been studied [89]. The use of Benzydamine for prevention of radiation-induced mucositis in patients with head and neck cancer receiving moderate dose radiation therapy is recommended [63]. Benzydamine hydrochloride oral rinse has been recommended to use for the prophylaxis and reduces the severity of radiation induced mucositis in head and neck patients because it is effective, safe, and well tolerated [84]. With its action of reducing tumor necrosis factor, it has demonstrated efficacy in reducing the intensity, frequency and duration of mucosal damage.

Xerostomia

Hyposalivation or xerostomia is the major complaint of patients who undergo conventional external beam radiation therapy to the nasopharynx area. A high dose delivery to the major salivary glands bilaterally leads to alteration of salivary glands function and reduction of resting and stimulated salivary flows. Parotid glands are at high risk to radiation damage [33, 90]. The magnitude of damage depends on the radiation dose, the volume of irradiated glands and the nature of the irradiated salivary glands. Radiation treatment for definitive treatment of HNC usually is conventionally given in daily fractions of 1.8 Gy to 2.0 Gy, up to total doses of 66 Gy to 70 Gy [65]. Approximately 88% of the patients observed had xerostomia after conventional radiotherapy [91].

An average person normally produces saliva at the rate of 1.000–1.500 ml per day. Salivary flow rates vary depending on the demand or the current physiologic status of the person, the non-stimulated or resting flow rate is 0.3 ml/min, and the flow rate during sleep is 0.1 ml/min, stimulated saliva as during eating or chewing increases to 4.0 to 5.0 ml/min [92]. Approximately 90% of all saliva is secreted by the major salivary glands; the parotid, the submandibular, and the sublingual glands. Less than 10% of the total saliva production is

from the minor salivary glands, which are scattered over the mucosal surfaces of the mouth and the pharynx. Unstimulated saliva mainly is secreted from the submandibular glands 69%, the parotid glands 26%, and the sublingual glands 5% respectively, while 70% of all stimulated saliva is produced from the parotid glands [93].

Salivary flows are markedly reduced following 10-15 Gy of radiation delivered to most of the gland as a loss of function of parotid gland can be observed [94]. During the first week of radiation, saliva may decrease by 50-60% and basal salivary reaches a measurable minimum within 2 to 3 weeks parotid gland salivary flow is markedly reduced following a cumulative dose of 30–50 Gy given with conventional fractionation [95, 96, 97]. With high doses of 60-70 Gy the salivary flow rapidly decreases, nearly ceases and rarely recovers [33]. The depression of salivary function varies among patients; however, gradual recovering of saliva function is possible over time, following fractionated radiation therapy provided that the total cumulative dose can be kept relatively low. Salivary function continues to decline for up to several months after RT [98]. The recovery of salivary function was observed within 12–24 months even with doses 40-50 Gy [96, 99, 100, 101]. This depends on the dose received by the salivary glands and the volume of the glandular tissue included in the irradiation fields; however, xerostomia generally develops into an irreversible, life-long problem [102, 103]. A recent study reported that salivary output could still recover many years after RT, with an approximately 32% increase in salivary flow from 1 year to 5 years after treatment [104]. However, high doses of radiation can lead to permanent glandular damage and permanent loss of salivary gland function [96, 100, 101]. The use of IMRT could reduce the mean doses of the parotids to less than 26 to 39 Gy and help save more than 25% of the preradiotherapy salivary flow rates [99]. The severity of xerostomia or grading of xerostomia (table 5) after IMRT observed was significantly lower compared to those after conventional radiotherapy [105]. Moderate to severe xerostomia were observed during therapy, but the spared salivary glands showed recovery over time [95]. However, xerostomia may occur later after treating with IMRT; studies reported 17-30% of patients had late grade 2 xerostomia [95], and 14% of patients experienced grade 3 xerostomia one year after IMRT [23]. According to National Cancer Institute (NCI) Common Terminology Criteria for Adverse Events Version 3.0 (CTCAE) [68], xerostomia can be graded as present on Table 5.

Table 5. The salivary gland and taste changes can be graded according to the clinical features and functional impairments (corresponding dietary limitations) [68]

Grade	Level of Salivary gland changes and taste alteration
Grade 1	Slightly thickened saliva Altered taste (e.g., metallic) but no change in diet
Grade 2	Thick, ropy, sticky saliva; Marked altered taste; alteration in diet required (oral supplements); noxious or unpleasant taste; loss of taste Secretion- induced symptom not interfering with activities of daily living (ADL)
Grade 3	Acute salivary gland necrosis; severe secretion- induced symptom interfering with activities daily living (ADL)
Grade 4	Disabling

Consequences of xerostomia

Most patients with reduction of saliva experience may complain of dry mouth, oral burning or soreness, a sensation of a loss of or altered taste. Difficulty of speech is also a common complaint of the patients who report self perceived problems [106].

Another manifestation is uncomfortable mastication and the oral manipulation of food is even painful. Most of the patients have an increased need to sip or drink water when swallowing, difficulty with swallowing dry or hard foods, which lead them to diet adjustments. Food easily gets stuck in their mouth or throat [107]. Decreased saliva output also predisposes the patients to fissures, ulcers of mucosa due to dryness [108]. The lack of saliva increases risks of dental caries and susceptibility to infection of the oral cavity and oropharynx, especially by the opportunistic fungus *Candida albicans*. Patients with xerostomia, who wear removable dentures (either full or partial), are at greater risk of developing denture stomatitis, a fungal infection, observed as erythematous mucosa underneath dentures and may contribute to their discomfort [109]. In addition, other complications, including pain from denture irritation and loss of retention are more likely to develop. The reduction of salivary flow may also contribute to the risk of osteonecrosis of the mandible and to esophageal injury by decreasing acid clearance by salivary bicarbonate [110, 111]. Finally, this combination of factors can result in decreased nutritional intake and weight loss, posing a major health problem for some patients and definitely result in decreasing of patients' quality of life [92, 96, 100, 101, 112, 113].

Prevention of Xerostomia

Several cytoprotective/radioprotective compounds have been developed to prevent the toxic effect of radiotherapy and/or chemotherapy to the normal tissue.

Amifostine has been accepted as a potential cytoprotective and radioprotector. It is used during RT with daily administration either intravenous or subcutaneous (350-500 mg) before each fraction of conventional RT. With higher daily doses (500 mg) it can be used for protection against large RT fractions or aggressive chemoradiotherapy regimens. Approximately 80-85% of patients treated with amifostine completed the whole course of RT with no significant side effects [114-117]. However, amifostine may be associated with adverse effects such as nausea and vomiting, malaise and fever or rash which can be found in 15-20% of patients. In addition, there is a risk of transient hypotension with the use of amifostine during intravenous administration. Although subcutaneous administration is not officially approved, it is widely accepted for its better tolerance and its convenience [116-118].

Salivary gland-sparing RT: It has recently become possible to spare a portion of the parotid gland by the implementation of 3-dimensional (3D) conformal RT (3D-CRT) and IMRT techniques in clinical practice. IMRT has the potential to reduce the dose to the salivary glands while simultaneously delivering a high dose to the tumor target. Therefore, IMRT may also decrease the toxicity associated with radiation therapy, especially xerostomia. The efforts to preserve the salivary gland function are not associated with an

increased risk of local recurrence [23]. In addition, with IMRT, a mean dose to the oral cavity <25 Gy is feasible and results in the sparing of the contralateral submandibular gland as well as the minor salivary glands, which are equally important in prevention of xerostomia [119].

Surgical transfer of a submandibular gland: The transfer into the submental space (out of the proposed radiation field) has been suggested in the prevention of radiation induced xerostomia [120, 121]. This is only practicable on a patient who has surgery followed by RT as treatment plan. The surgical transfer of salivary gland is done as part of the surgical intervention. Studies showed all of the glands transferred survived and functioned well; the surgical technique had no complications and added an average of 45 minutes to the surgical protocol. The high results in xerostomia prevention are observed up to 80% and the long-term follow-up and reported normal amounts of saliva 2 years after RT in 83% of patients who had salivary glands transferred [122-124]. The limitations of the technique are the cases selection and the submental space cannot be shielded because of its proximity to the disease. A study reported 28.3% of patients who underwent salivary gland transfer were without subsequent RT or without sparing of the relocated gland [125]. Therefore, salivary gland transfer should not be considered as a standard procedure.

The gene therapy and the development of future viral vaccines for cancer therapy and further clinical controlled trial studies should be continued [126, 127], and possibly the stem cell transplantation.

The Management of Hyposalivation and Xerostomia

The management of hyposalivation usually is a palliative treatment for the temporary relief of dryness and prevention of other oral complications including;

Frequent sipping of water: the practice of carrying and sipping bottled water throughout the day is well accepted, it may also offer relief for affected patients. Water spray may be used for oral hydration and lubrication. Swishing ice chips or ice water may be used to provide moisture and possibly alleviate symptoms.

Saliva substitutes are used for the lubrication, hydration of the oral tissues and maintaining oral health and functions. There are many artificial saliva substitute products available in a variety of formulations including rinses, aerosols, chewing gum, dentifrices, etc. [85]. However, saliva substitutes cannot replace saliva, since they usually do not provide the same protective roles; the antibacterial and immunologic protection as natural saliva. Besides, their duration effect is often shortened by swallowing and additionally there are some complains of poor tolerance, oily consistency and sticky feeling. In addition, there are very few supporting evidences that can promote saliva secretions function for patients with xerostomia.

If there is some residual salivary function, the use of systemic sialagogues can help stimulate saliva production from residual intact gland tissue. There are some agents that are used such as pilocarpine, cevimeline and some other drugs.

Pilocarpine is a natural alkaloid that has a principal role as a muscarinic-cholinergic agonist with mild β -adrenergic activity. As a parasympathomimetic agent, it renders the stimulation of cholinergic receptors on the surface of exocrine glands which result in

diaphoresis, salivation, lacrimation, and pancreatic secretion. The use of 2.5-10 mg pilocarpine HCl per oral three times daily for 4-12 weeks has been shown to improve the saliva flow rate in approximately 50% of patients with radiation-induced xerostomia, although, in some cases the improvement can be observed as late as up to 90 days [128, 129]. For optimal results, it is recommended to treat the xerostomia patient and also use a maintenance therapy during longer treatment periods [130, 131]. In addition, surveys showed a statistically significant patient-perceived improvement in either the sensation of oral dryness or in the sensation of overall xerostomia. However there are contraindications of pilocarpine which should be carefully considered before it being prescribed to the patients especially when used in the patients who have chronic obstructive pulmonary disease and cardiovascular disease. It is actually contraindicated in patients who have asthma, acute iritis, or glaucoma. A variety of side effects of pilocarpine, caused by a generalized parasympathetic stimulation can be observed: mild-to-moderate sweating is common (50%), as well as frequent urinary, lacrimation, and rhinitis. In addition, chills, nausea may be observed [130, 132-135]. The administration of pilocarpine before or during radiation and the beneficial effect to lessen the frequency and severity of xerostomia from radiation-induced remain controversial [136, 137].

Cevimeline is also muscarinic agonist that has been found safe and effective in treating xerostomia in patients with treatment of radiation-induced xerostomia [138]. Sugar-free chewing gum and sugar-free candies or lozenges may help to increase salivary output but they may be inconvenient and effect patients' compliance particularly in those who wearing full denture [54].

The most important is rigorous oral hygiene and regular dental care. Plaque and food debris can easily accumulate due to the reduction of saliva flow and loss of saliva flushing action. Frequent care of oral hygiene is necessary. It is compulsory to use mechanical plaque removal by tooth brushing, flossing and other oral hygiene aids for more adequate cleaning. Water irrigation may be used to help cleaning the teeth. Rinsing with a solution of salt and baking soda 4 to 6 times a day (mix 0.5 teaspoon of salt and 0.5 teaspoon of baking soda in a cup of warm water) helps cleaning and lubricating the oral tissues as well as buffering the oral environment.

Remineralization the teeth by using high concentration fluoridated toothpaste, rinsing with 0.05% fluoride mouthwash or applying high concentration prescription fluorides at bed time are recommended for daily use as long as xerostomia persists. In children, both topical and systemic fluorides are necessary. The use of other remineralizing products such as casein phosphopeptide stabilized amorphous calcium phosphate (CPP-ACP) as adjunctive treatments to fluoride therapy demonstrated beneficial outcome [139].

A soft and moist diet is usually recommended for xerostomia. Cariogenic foods and liquids with high sugar content should be avoided. Dry food such as bread, dry meat, pastries, toast and crackers, snack crispy salty foods are not suggested. Diet rich in raw dark green leafy vegetables may help moisturize the mouth. If the patients have difficulty chewing and swallowing food, soaking bread or rolls in milk should be tried, as well as drinks or sauces before eating; this will help ease with chewing and swallowing. In the more severe cases, liquefying and pureed food are recommended [54].

For prevention of dryness of the lips and reducing risk of lips injury in chemotherapy patients, lip care products containing petroleum-based oils and waxed can be used. However, during radiation, a non petroleum lip balm for dryness of the lips is recommended. Lip moisturizing should be applied often to help prevention of dryness and cracked lips [140].

The taste of many common dentifrices is too strong for xerostomia patients. The detergents such as sodium laurylsulfate contained in these dentifrices are too harsh for the fragile mucosal surfaces of patients with dry mouth. Therefore, special dentifrices with mild taste have to be used [85].

Mouth breathing and xerostomia may worsen the dryness of the lips. In patients with comorbid diseases, some prescribed medications can worsen dry mouth [140]. The use of soft denture liners is recommended in patients with problems with denture retention [54].

Oral and Systemic Infections

Infections emerging from the oral cavity are significant problems in cancer patients treated with intensive chemotherapy regimens, including hematopoietic stem cell transplant (HSCT) procedures. It may be seen in patients with radiotherapy; however, it is more common and more severe with chemotherapy, which may be seen during and after cancer therapy [141]. It is more common and more severe in chemotherapy treated patients than in irradiated patients [44]. During profound neutropenia, patients are particularly at risk of developing infections caused by oral bacteria, but fungi and viruses may also play a part. A substantial number of these infections are associated with oral mucositis or arise from ulcerated oral membranes of mucositis, which is the effect of complex interaction between the toxicity of cancer chemotherapy to oral mucosal tissues, myelosuppression, and the oral microflora [141]. The other important factor that increases the risk of oral infections is the reduction of salivary flow, as it leads to decreased production of electrolytes, immunoglobulin, lysozymes and peroxidases, losses of saliva buffering capacity and lowered pH of saliva. The levels of cariogenic microflora; *Streptococcus mutans*, *Lactobacilli* species and *Candida* spp. significantly increase [32, 142, 143]. In addition, there is evidence that pre-existing infections of periodontal tissues (gingivitis and periodontitis) are associated with fever and sepsis in these patients. Ulcerated periodontal pocket epithelium can act as a portal of entry for translocation of microorganisms into the bloodstream. In addition, inflamed and infected periodontal tissues may serve as a reservoir of endotoxin (lipopolysaccharide, LPS), pro-inflammatory cytokines, and other inflammatory mediators which may spread systemically [44, 45].

Candidiasis is the most common infection in the oral cavity during or shortly after radiotherapy, its risk continues with hyposalivation [142]. Infections can occur during mucositis and disseminate systemically from the ulceration and inflammation of mucosal. The prevalence of positive *Candida* cultures increased from 43% at baseline to 62% at completion of radiotherapy and to 75% during the follow-up period [142]. Some authors believe that oral mucositis is aggravated by fungal infections [144]. However, treatment of yeast and Gram-positive cocci with topical anti-fungals and disinfectants failed to relieve such complications [145, 146]. Thus, many of the oral lesions observed during treatment do

not seem to be caused by candidiasis or streptococcal infection. Oral candidiasis commonly manifests as pseudomembranous (white, curdlike patches that adhere to the mucosal surfaces), hyperplastic, or atrophic (erythematous) oral lesions and angular cheilitis (inflamed fissures at the corners of the mouth). It can be occasionally invasive, resistant to treatment, and potentially lethal. Particularly in children undergoing chemotherapy, systemic candidiasis can develop into a medical emergency [44].

The patients wearing dentures are at greater risk of fungal infections, since the mucosal irritation and decreased healing of soft tissues may be altered in post-radiation mucosa. In addition, *C. albicans* can easily adhere to irregular and porous surfaces of denture acrylic, thus it can become a reservoir for this typical yeast. Besides, candidiasis associated to dentures is also related to poor hygienic condition of the prostheses, the prolonged usage and the modifications of the hard supporting tissues. Continuous denture wearing is a predisposing factor of candidiasis [109].

Management of oropharyngeal candidiasis; antifungals are regularly used after the detection of oral candida including systemic and topical antifungal.

Systemic azole antifungals are effective in reducing overall oral fungal colonization levels and the frequency of fungal infections. Fluconazole is recommended as the drug of choice for antifungal treatment, especially in resistant fungal infections. Recommended administration of fluconazole: once daily 50 or 100 mg tablets or 50 mg per 5 ml of suspension 4 times daily. Azoles may be used as prophylactic antifungals in the radiotherapy patients [142, 147, 148]. Even though nystatin has been effectively used as antifungal for a long period of time, several studies indicated that the use of nystatin suspension ineffectively reduces the incidence of oropharyngeal candidiasis in the patients receiving chemotherapy or radiation [149-153]. In addition, using nystatin concurrent with chlorhexidine is not recommended because of their antagonistic effects. If it is unavoidable, the administration of one drug should be at least one hour apart from the other [150, 151].

Topical antifungal can be used such as miconazole varnish or gel (25 mg per ml) by applying a thin coat to the affected areas for 4 to 5 times daily. For patients wearing dentures, the application to the inner surface of dentures should be done. However, for patients on warfarin, the use should be avoided because the increasing anticoagulant effect [154]. Topical antifungal mouth rinses can be used by rinsing and holding in the mouth for a few minutes to ensure that the whole mucosa is coated. Dentures should be removed to allow contact between mucosa underneath and the antifungal rinses. The integration of an antifungal with a denture liner is recommended to those who have problems holding the antifungal in their mouth for a few minutes [109]. Other antifungals are 10 mg of clotrimazole troches dissolved in the mouth 4 to 5 times daily and ketoconazole or itraconazole as systemic medications.

Maintenance of good oral hygiene and topical antifungals usually are sufficient for uncomplicated candidiasis. Oral hygiene measures should include cleaning the teeth, the oral mucosa surfaces and the dentures. Dentures should be removed overnight. It is recommended that they should be left out at least 6 hours. Daily cleaning and disinfecting denture is essential when not wearing it. Brush the denture with long soft bristles brush might not be effective for removal of fungus, since acrylic denture has irregular and porous surfaces which harbor *Candida* easily. Soaking denture in a denture cleaning solution, such as antiseptic

solution and chlorhexidine can be done. After disinfection, dentures should be left to air dry, as it is good to eradicate the fungus. Discoloration of dentures and natural teeth can be observed using chlorhexidine if not adequately removed after disinfection. A new denture should be replaced if it is poorly fitted and frequent repeated infection.

Bacterial infection is increased in the radiotherapy patients especially *Streptococci mutans* and *Lactobacilli*, infection due to the loss of saliva protective and buffering effects. In myelosuppressed cancer patients, systemic infections of gram-positive organisms including *Streptococci viridans* and *Enterococci* spp. are usually from oral origin. Radiotherapy is also associated with a noticeable increase in oral gram-negative pathogens including *Pseudomonas aeruginosa*, *Neisseria* spp. and *Escherichia coli*; their endotoxins can cause adverse systemic effects [32, 43, 44]. Patients with chronic periodontal disease may develop acute periodontal infections with associated with systemic sequelae. Extensive ulceration of sulcus epithelium may be not directly noticeable, yet it could be a source of disseminated infections. Signs of gingivitis may not be seen due to the underlying myelosuppression [141, 155]. Prophylactic antimicrobials can be used to prevent oral infections and dental caries, aqueous based mouth rinses of 0.12% or 0.2% chlorhexidine have been demonstrated to be beneficial. Alcohol based chlorhexidine solutions should be avoided due to the exacerbation of xerostomia and mucositis [143, 146, 156, 157]. Some clinical studies indicated that topical use of polymyxin E and tobramycin 4 times daily have been effective [158].

Viral infection in the oral cavity of cancer patients: the most common are Herpes simplex virus (HSV) and Herpes varicella zoster virus (VZV). However, cases of Cytomegalovirus induced ulceration have been occasionally reported. In children undergoing chemotherapy, acute herpetic gingivostomatitis with systemic involvement is considered as medical emergency [44, 159, 160, 161]. Acyclovir is the most useful antiviral agent for HSV and VZV infection. Valacyclovir can reduce the incidence of oral HSV infections. Prophylactic use of acyclovir and valacyclovir are effective reducing recurrent viral infections in children and adults who receiving bone marrow transplantation or immunosuppressed cancer patients [159, 162-165]. Prophylaxis antiviral for prevention of mucositis using acyclovir and its analogues are not recommended for routine use [71]. Acyclovir is effective in reducing herpes simplex virus (HSV) infection even in patients with leukemia or lymphoma, [22, 117]. However, oral mucositis still develops in patients routinely receiving acyclovir or one of its products for prophylaxis. This suggests that HSV infection plays little or no role in causing oral mucositis. Finally, it should be mentioned that HSV infection is not a significant contributing factor in irradiation mucositis. This is in contrast to the commonly seen HSV re-activation following chemotherapy and radiochemotherapy patients [32, 166].

Taste Dysfunction

The impairment of the taste function results from direct radiation damage to taste receptors which usually can be observed as early as in the first week of therapy. The degeneration and atrophy of taste buds regularly occur at radiation dose of approximately 10-20 Gy, though it may not be observed clinically. The problems gradually increase according to the accumulation of radiation dose: at a dose of 60 Gy, in over 90% of patients observed,

the taste buds were almost completely destroyed with a relative taste loss [167]. The variation of taste function impairments could be observed including a reduction in taste sensitivity/perception (hypogeusia), an absence of taste sensation (ageusia), a permanent impairment in sensation or a distortion of normal taste (dysgeusia) in patients receiving external beam radiotherapy [168]. At the dose of 30 Gy, 50% of the patients observed had taste loss, involving all 4 tastes (sweet, sour, bitter, and salty) [169]. Perception of bitter is more susceptible to damage, is earlier revealed and shows a greater impairment than others, while the sweet quality is the least [170]. However, the occurrence of loss of all tastes perception is rare [171].

Irradiation on the taste buds may not be the only causes of the loss of taste, but the reduction in salivary flow rate also relates to taste dysfunction and often contributes to the slow return of taste perception after RT. The decreased transport and solubilization of gustatory stimulants reduces the ability of saliva to protect the mucosa against bacteria, fungi, and variation in the oral pH, alters the ionic composition of saliva, which is important for taste, and affects mastication, nutrition, and the hedonic aspects of tasting [172].

Although the loss of taste does not seem to be a major complaint among patients with xerostomia, the level of hyposalivation should be assessed, since adequate moistening and lubrication of the oral tissues and food are essential for food intake and the eating ability of the patients [173]. Effect of impairment of taste function after radiation therapy: many patients may complain that food tastes differently and displeasing, due to either loss of taste or impairment of the perception of the various flavors which can result in reducing appetite and the changing of food intake and lead to weight loss [174, 175].

Dietary counseling is also of great help in adapting to the taste of food, since the perception of the various flavors in many patients does not change in the same extent. Consequently, food that was enjoyed by the patient before radiation treatment can often have a less pleasant taste after treatment. Food with pleasing taste, color, smell and substitution of food aromas for the sense of taste may improve the patient's food intake [39]. Thus, a basic meal plan including the addition of supplementary feedings should be started at the beginning of therapy and followed, with modifications, during at least the total period of treatment. In addition, dietary counseling should carry on until the complaints subside or the patient has adapted to the new situation even though the taste gradually return to near normal. Additionally, in patients with head and neck cancer or those with malignancies at other sites, the perception of abnormal taste (one or more tastes change) is frequent before the beginning of radiotherapy or chemotherapy [168].

In general the loss of taste is transient, thus no treatment is necessary. Partial improvement can be observed within 3-10 weeks end of radiotherapy. Taste functions gradually return to nearly normal or fully recovery within 4-12 months; however, it may be up to five years depend on the amount of radiation received [176]. Zinc supplements are proven to improve the supportive care of patients with taste alterations resulting from head and neck cancer [168, 177].

Prevention of taste loss can be best accomplished through direct protecting of healthy tissue or placement of these tissues outside the radiation field by means of shielding or repositioning prostheses. A reported cytoprotection against the loss of taste by the administration of amifostine during a course of radiochemotherapy is controversial [117].

However, the acceleration of taste improvement in the post-radiotherapy period brings more benefits than the preservation of taste during radiotherapy [39].

Dysphagia

Dysphagia is a common, distressing and potentially life threatening sequelae of chemotherapy and radiotherapy. The surgical intervention and location of cancer also carries significant morbidity. Both severe speech and swallowing dysfunction were demonstrated after surgical resection of the oropharyngeal area which was related to the volume of tongue and soft palate resected. Long-term swallowing difficulty was also noted after resection because of abnormal movement of the tongue base and pharyngeal wall. The severity of the speech and swallowing disorders depends on the site of the primary tumor, the stage of the disease, the type of surgical resection used, and the quality of the graft [176]. Compounded by postoperative radiation xerostomia and scarring or disfiguring of the pharyngeal muscles accumulate the problem, which frequently leads to patients' anxiety and depression of cancer survivors [24, 25, 176, 177]. During mucositis and pain, dysphagia may be more severe which may lead to malnutrition, dehydration and other consequences. Acute mucositis and consequential late fibrosis as well as dysphagia are major factors limiting the intensity of therapeutic regimens for head-and-neck cancer [178, 179].

After radiation, inhibition of deglutition reflex occur; the patients gradually develop difficulty in swallowing solid foods or liquids, which may require prolonged tube feedings or repeated dilatations.

Depressed cough reflex may cause aspiration in patients which may lead to aspiration pneumonia. Approximately 8% of the patients developed esophageal strictures after treatment requiring repeated dilatations and 37-45 % developed severe dysphagia or aspiration which required prolonged tube feedings for more than 3 months [6, 180-183].

Once chronic dysphagia has occurred, swallowing rarely returns to normal. In severe cases the depressed and the absence of cough reflex may be observed and causes aspiration in patients, which leads to aspiration pneumonia and becomes the cause of death. A high rate of aspiration was observed in 16% in patients, who underwent concurrent chemotherapy and radiation [6, 183].

According to NCI Common Terminology Criteria for Adverse Events Version 3.0 (CTCAE), dysphagia can be graded as follow (Table 6) [68].

Management of patients with dysphagia is to provide adequate oral nutrition and to maintain safety when eating and drinking. Dietary modifications are to ease swallowing ability which depends on the level and severity of dysphagia. Puree diet are for the patients with minimum chewing ability, semisolid foods for the patients who have some chewing ability and soft solid food for those with greater chewing ability. Creating a calm, quiet atmosphere during meals helps patient relax and focus on eating. Postural modification of swallowing has been observed that the risk of aspiration is significantly diminished in patients with head-and-neck cancer after surgery [184].

In irradiated patients, instruction of a practice designed to close the entrance to the airway early in the swallow was found to be successful in reducing the incidence and amount of aspiration [185].

Table 6. Dysphagia grading and swallowing functions according to NCI (National Cancer Institute) Common Terminology Criteria for Adverse Events Version 3.0 (CTCAE) [68]

Grade	Level of dysphagia (Swallowing difficulty)
Grade 1	Symptomatic, able to eat regular diet
Grade 2	Symptomatic and altered eating/swallowing (e.g., altered dietary habits, oral supplements); IV fluids indicated <24 hrs
Grade 3	Symptomatic and severity altered eating/swallowing (e.g., inadequate oral carolic or fluid intake); requiring intravenous (IV) fluids, tube feedings or TPN ≥24 hrs
Grade 4	Life-threatening consequences (e.g., obstruction, perforation)
Grade 5	Death

Enteral feeding such as the use of gastrotomy tubes helps preventing malnutrition and prolongs life. However, there are some disadvantages observed in long term tube feeding (over 3 months), the patients become dependent and develop severe dysphagia and chronic aspiration due to excessive fibrogenesis. Modified barium swallowing may be useful to determine the need for long term tube feedings and for swallowing therapy. Oesophageal dilatation may be required in those who are at risk of oesophageal strictures and need the swallowing therapy [6].

The use of amifostine during chemoradiation has been observed to significantly reduce the incidence of dysphagia and fibrosis in patients with head and neck cancer; however, further studies should be done [117].

It is suggested that the patients demonstrating aspiration receive consultation and periodic follow-up with the speech-language pathologist for management of post-therapy dysphagia and practice to increase the efficiency of the swallowing and to reduce the risk of aspiration. Future studies are needed to assess the clinical impact of these preventive measures [183].

Oral Care during Cancer Treatments

Regular oral examination and treatment throughout active cancer treatment and follow-up are as important as the one prior to the beginning of cancer therapy so as to identify oral complications at an early stage, and to coordinate oral care [71, 141].

During chemotherapy, continuous maintenance of good oral hygiene is recommended to prevent the accumulation of dental plaque. Routine dental treatment may be performed as usual if the granulocyte count is more than $2,000 \text{ mm}^3$ and the platelet count is more than $40,000 \text{ mm}^3$ [81]. However, tooth extraction during chemotherapy is contraindicated; periodontal probing and other procedures to diagnose periodontitis should be avoided. If an

emergency is needed for the patients with low platelet and white blood count, all dental procedures should be carefully performed without trauma to the soft tissues, antibiotics prophylaxis should be administered under supervision of the oncologist. Symptomatic treatment may be performed such as pulpectomies and temporary fillings therefore the teeth may be reopened for relief pain when needed until tooth extraction is allowed. Platelet infusion may be needed in the patients who undergo invasive dental procedures. Splints may be required to control hemorrhage [56, 186].

During radiation, invasive dental treatment should be avoided; extraction of teeth or wounding during radiation therapy will create an extremely high risk for osteoradionecrosis and is strongly discouraged [187]. Occasionally when there is an emergency, palliative treatment such as temporary dressing is recommended. Definite dental treatments and removal of teeth during radiation should be delayed until radiotherapy finishes and the mouth has healed from mucositis and dermatitis reaction.

The use of topical fluoride should be continued, during this period toothpastes and fluoride gel may be irritate in some patients. The change to mild flavoring toothpastes is beneficial or brush with salt water if mild toothpaste still irritate patients should be encouraged to have their mouth clean at all time despite on tube feeding [54].

The Oral Complications after Cancer Treatment

After cancer therapy complications remain significant for the combined treatment modality. There is a variety of oral complications demonstrated after cancer treatments; the common observed are trismus and dental caries. Additionally, dysphagia and risk for aspiration can be observed. However, the late xerostomia may be observed a year later after radiation and the more severe as osteoradionecrosis may develop as well.

Trismus

Trismus, a limited mouth opening is a common complication following head and neck cancer treatments especially those who had surgery and/or radiotherapy. Limited mouth opening have a tendency to develop early post radiotherapy although it may not be noticed until 3-6 months after completed treatment (Figure 2) [39]. There are many causes of trismus which include the direct effect of radiation that gradually cause fibrosis and contraction of masticatory muscles and/or temporomandibular joint (TMJ) in the radiation field or a combination of both which eventually carry on [40]. Radiation doses > 70 Gy are associated with the greater degree of reduced mouth opening [40, 91, 188]. In addition, there was no significant difference of incidence of trismus observed between patients treated with IMRT and those treated with conventional RT [189]. Regarding the muscles in the radiation field, when the sternocleidomastoid and pterygoid muscle are included in the treatment portals, a greater amount of limitation in mouth opening occur [39, 40]. Tumor penetration into masticatory muscles and/or the TMJ induces a reflex contraction which prevents the stretching of mouth closing muscles results in limitation of mouth opening. Surgical

procedures resulted in fibrosis or scarred of the tissues in the area of TMJ. In those who had surgery or radiotherapy, the prevalence rate of trismus is much higher than those in newly diagnosed patients. Other reasons leading to difficulty in mouth opening could be due to an insufficiency of mucosa lubricated that lead to pain and discomfort [39].

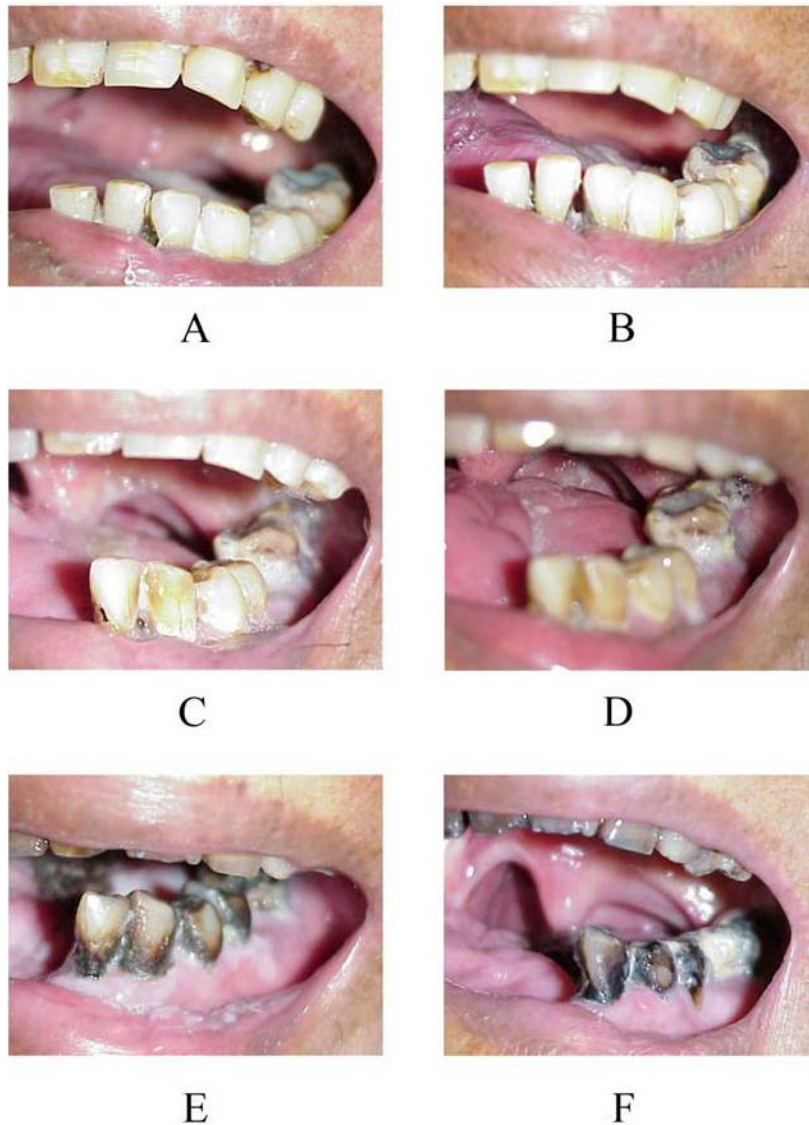


Figure 2. Development of trismus and radiation caries; beginning of RT (A), ended of RT (B), follow up at 9, 12, 18, 24 months (C-F).

Approximately 47% of patients with hyposalivation and 16% with mucositis were observed to have mouth opening difficulty due to pain or lack of oral lubrication, which is misleading in representing the real capacity of mouth opening [190]. Besides, the patients may present altered mandible movements even if the TMJ and pterygoid muscles were not included in the radiation field [40]. Anxiety, depression or the stress associated with cancer

or because of sleep disorder may lead to temporomandibular dysfunction (TMD) that cause trismus [191]. Additionally, other possible causes of trismus or severely restricted mouth opening result of intra capsular pathology of the TMJ or of extra capsular pathology. Extra capsular causes of trismus include peritonsillar abscess, dental infections, noma, trauma to mouth closing muscles, complication of post mandibular nerve blocks, tetanus, and submucous fibrosis due to chewing betel nut [192].

Trismus can lead to pain, inflammation, and degenerative changes to TMJ. Once it occurs, it is frequently irreversible and becomes a lifelong problem. Early intervention is essential to minimize the effects of trismus, since the severity of trismus increases with long period of time. The effects of limited mouth opening lead to compromised oral hygiene, brushing may be difficult approaching lingual surfaces of the teeth as well as flossing. The use of small size brush may help with the moderate cases. In the severe cases the modified use of other oral cleaning aids fit for the individual's need may help conjunction with frequent mouth rinses. Oral examination and adequate dental treatment are difficult and hard to obtain. Dental procedures are especially complex if trismus is combined with xerostomia. Trismus can lead to difficulty chewing and/or swallowing, reduce nutritional intake that contribute to weight loss, and increase risk of aspiration. Impaired speech, a negative impact on quality of life and depression can be anticipated [188]. In children the effect of high dose of radiation to condylar cartilage of temporomandibular joints (TMJ) may cause TMJ ankylosis and the consequences effect the growth and movement of jaw, mal-development in the craniofacial skeleton that may affect the facial esthetics such as micrognathia [32].

Treatment of trismus to keep the maximum mouth opening; inter-arch or inter-incisal distance should be frequently measured before during and after radiotherapy to ensure its maintenance. A careful assessment should be done since the prevention is better than the treatment. Patients who have the risk of trismus should be instructed home exercises to maintain maximum opening and jaw mobility [40, 193].

For those who have developed trismus, the treatment procedures usually include: stretching connective tissue, strengthening the weakened muscles, mobilizing the joint, as well as reducing pain and inflammation. Several mechanical methods have been promoted for the treatment of trismus such as the use of tongue depressors and finger stretching, spring appliances, acrylic cones/wedges, rubber stops and clothes pegs, but none has been shown to be effective in adequately sized and controlled studies [189].

The exercise program should be intensified and, if necessary, combined with physiotherapy such as massage, moist heat application and gentle stretching to regain the lost inter-arch distance. The patient's compliance and persistence are fundamental of success, regardless the approach to this problem, since the results are not to remarkably accomplished without delay [193]. Medications with muscle relaxants, anti anxiety agents and the use of 400 mg pentoxifylline 2 to 3 times daily have been shown to ease mouth opening [39, 192].

Surgical removal of scar tissue or a coronoidectomy and the release of temporalis and the medial pterygoid muscles may be performed. Physical therapy and exercise therapy should be performed until mouth opening stabilized approximately a month after surgery [192].

Osteoradionecrosis

Osteoradionecrosis (ORN) is a serious and debilitating complication in patients undergoing radiotherapy for HNC. The patients may present the symptoms, including chronic non healing wound of more than 6 months, pain, oro-cutaneous fistula, trismus, eating, swallowing and speaking difficulties, malnutrition, pathologic fracture, narcotic drug dependence, and loss of soft tissue, skin, and bone (Figure 3, 4) [54, 194].



Figure 3. Chronic non-healing wound at the mandible (A), fistula opening of non-healing wound (B).

Pathophysiology of ORN starts when radiation affects osteocytes, osteoblasts, and endothelial cells produces the “3 H effect” *i.e.* hypocellular, hypovascular and hypoxia to the soft and hard tissues [49]. The hypoxic tissue may develop avascular necrosis and tissue breakdown from the collagen synthesis and cell replication that are not be able to overcome collagen lysis and cell death [195]. This condition will present clinically when the tissue is traumatized from dental prosthesis, infected ulcer, or surgery. Later, the traumatized tissue becomes a chronic non-healing wound due to the poor reparative capacity of the body. The non-healing wound will be the access for bacteria and create infection to the avascular necrosis and lead to the full stage of ORN [49].

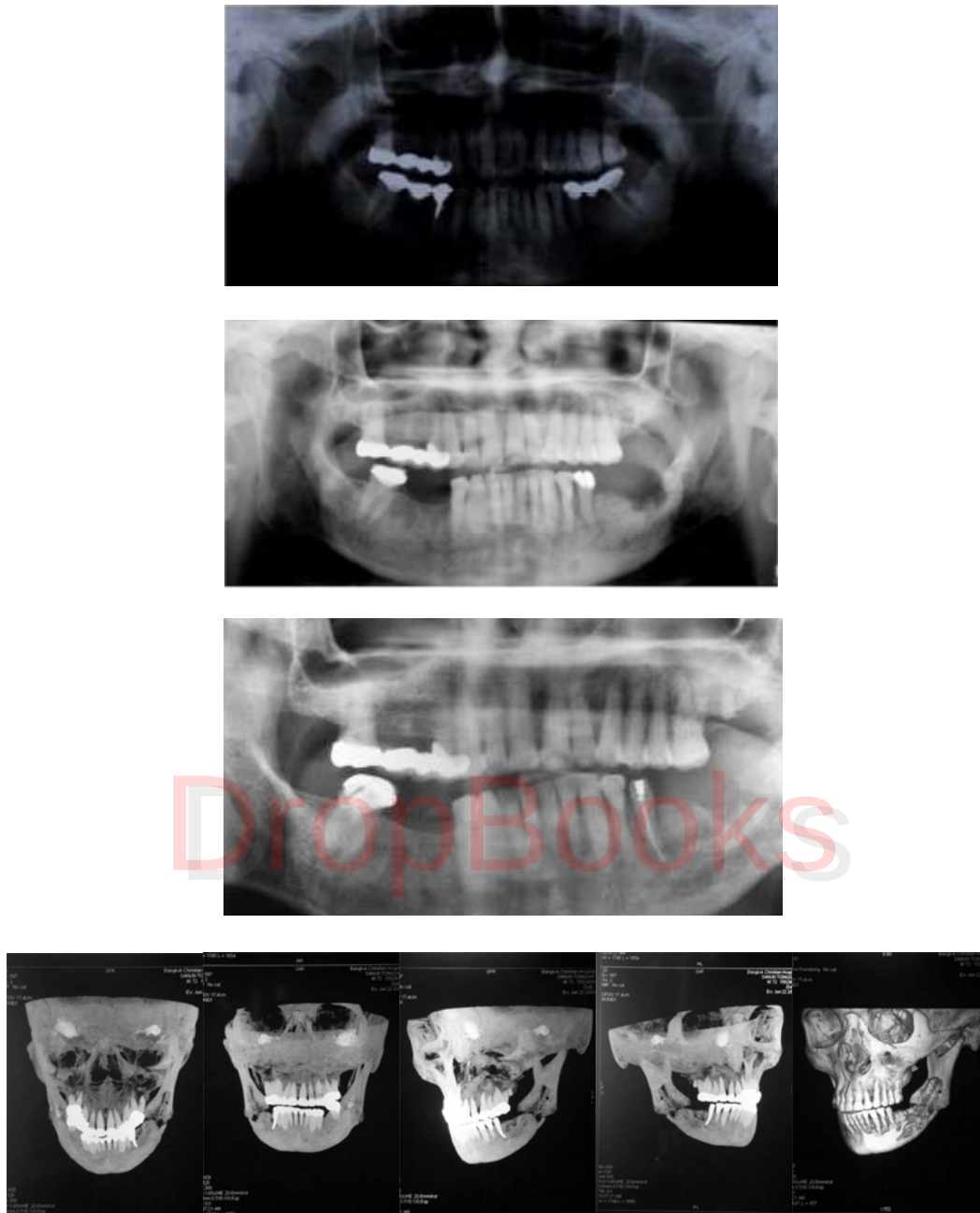


Figure 4. Panoramic radiographic images of the mandible before tooth extraction (A), osteoradionecrosis developed at the extraction site (B), sequestrum of the mandible (C), Anterior, posterior, buccal, and lingual view of 3D CAT Scan demonstrated pathologic fracture in ORN patient (D).

The most common site of ORN is the mandible, because its main blood supply is only from inferior alveolar vessel, which is different from the maxilla; however, ORN can occur in the maxilla and sternum [196, 197]. The incidence of ORN has declined due to the modern

radiotherapy techniques and the good supportive care from the dental professional. Presently the incidence of ORN from the pooled studies was approximately 3% [194].

ORN can be classified into 2 types, which are spontaneous ORN and trauma-induced ORN. Spontaneous ORN usually occurs within 6-24 months after the cessation of the radiation therapy. It is the result of process of cell death from radiation beyond repair and remodeling process which lead to the chronic non healing wound.

Trauma induced ORN is the result from trauma to the bone and soft tissues, such as tooth extraction and surgical treatment in irradiated field shortly before or after radiation as well as the dental prostheses. It occurs as bimodal peaks, which are at first 3 months and during 3-6 years after radiation treatment [49, 198].

There are multiple factors that might be associated with the occurrence of ORN which are useful for evaluating ORN developing possibilities in irradiated patients. These factors influence the occurrence of ORN including the location, stage or the extension of the cancer. The advance stage or the larger cancer will need more radiation dose and an extended area of radiotherapy [36, 199, 200]. Different tissues have various levels of tolerance of radiation damage [201]. The site of the cancer: tumors that occur on the anterior floor of mouth have less chance to develop ORN than the posterior floor of mouth cancer [49, 198].

The dose and technique of radiotherapy; the higher the radiation dose, the more tissue injury occur, and the greater the risk of ORN. These effects are more prominent and patients will have a high probability to develop ORN if cumulative radiation dose to the bone exceed 65 Gy. [42, 199, 202-204]. The size of radiation treatment field, dose per treatment, total radiation doses and combination interstitial implant and external beam regimen are associated with the occurrence of this radiation related side effects [49, 195, 198]. Interstitial radiotherapy produces more tissue damage and also creates a higher risk of ORN [205, 206]. The combination of cancer treatments renders high risks of ORN [207, 208]. The complexity and/or technique and the time of the oral surgery before and after radiotherapy have been observed to influence ORN [47, 198-200, 209, 210]. A two-fold increased risk of ORN was observed if dental extraction was done after radiotherapy compared to pre-irradiation therapy [198]. The host factors: patients who are with comorbid diseases, compromised nutritional status, and substances abuse such as consumption of tobacco and alcohol. Decreasing host immune responses affect the ability to repair tissue damage from radiation and different tissues have various levels of tolerance of radiation damage [207-210]. Dentate or edentate patients: the dentate patients have higher probability to develop ORN than edentate patients [211, 212]. Teeth with sharp edge, improper restorations, non-opposed and malocclusion can cause trauma to the oral mucosa, as well as the poor fitting prostheses

Patients with poor maintenance of oral hygiene aggravate the infections and bring a high risk of ORN in irradiated patients [198, 199, 213, 214].

The Management of ORN

The optimal precautions should be implemented before and during radiation in order to minimize the risk of developing ORN which has been described earlier, including the improvement of radiotherapy and shielding for the prevention of ORN.

Treatment of ORN has two objectives which are to eliminate the necrotic bone and improve in the vascular of the remaining radiation-damaged tissues [32, 215].

The majority of ORN heals spontaneously without any treatment. When there is a small lesion of ORN of the bone, the recommended treatments are prescriptions of daily saline irrigations and antibiotics [198].

For the advanced stage of ORN (which includes pathologic fracture, orocutaneous fracture, or the necrotic bone involving the inferior border of the mandible, fistula or full-thickness devitalization of bone), débridement of all non vascularized or necrotic bone is necessary to eliminate any nidus that is potential cause of infection and inflammation. However, the debridement does not support the improvement of the vascular of the adjacent tissue bed and the remaining vascularized bone. These tissues remain compromised by the past radiation and are persistently risk for the probable development of ORN. The surgical managements of ORN include saucerization, sequestrectomy, and resection with the reconstructive surgery. The surgical resection of the mandibular segment with free vascularized bone grafting seems to be the standard of care. Nonetheless, the treatment protocol is based upon the actual lesions of ORN that require an effective clinical staging system, particularly for lesions in the mandible [216, 217]. Osteonecrosis grading according to NCI (National Cancer Institute) Common Terminology Criteria for Adverse Events Version 3.0 (CTCAE) was presented on Table 7 [68].

The system developed by Marx was presented on Table 8 [195, 218], and Epstein's clinical staging system of ORN which emphasize on its pathogenesis. ORN can be classified as resolved, chronic, persistent, or active progressive, either with or without pathologic fracture [217]. The modified Epstein's clinical staging system of ORN was done recently, by focusing on the extent and nature of soft-tissue necrosis rather than on the presence or absence of a fracture. They proposed three stages, subdivided into stages with and without soft-tissue necrosis [216].

Table 7. Osteonecrosis grading and clinical features and correspondent managements according to NCI (National Cancer Institute) Common Terminology Criteria for Adverse Events Version 3.0 (CTCAE) [68]

Grading of ORN	Clinical feature and correspondent managements
Grade 1	Asymtomatic, radiographic findings only
Grade2	Symtomatic and interfering with function, but not interesting with ADL; minimal bone removal indicated (i.e.,minoe sequestrectomy)
Grade 3	Symtomatic and interfering with ADL;operative intervention or hyperbaric oxygen indicated
Grade 4	Disabling
Grade 5	Death

Table 8. The severity stages of ORN according to the response of managements [195, 218]

Severity stages of ORN	The response to correspondent managements
Stage 1	Heal completely after receiving 30 dives of HBO
Stage 2	Resolves after the 30 dives of HBO, with local debridement or surgery and followed by another 10 dives of HBO
Stage 3	Not response to the HBO and local surgical debridement or presents Requires the resection and the reconstructive surgery for the involved jaw.

The Marx protocol: the combination use of antibiotic therapy, hyperbaric oxygen therapy, and tissue debridement has been developed to improve healing of radiation induced injured tissue and increase the vascularization permanently [64, 204, 215, 218-223]. This protocol is extensively used, although, there is some controversy whether HBO is always necessary in cases of minor osteoradionecrosis.

Hyperbaric oxygen therapy (HBO) has been used to help the repairment of radiation induced ORN especially in patients receiving high doses of therapy (>50 Gy) [207, 216, 217]. HBO therapy stimulates angiogenesis, increases neovascularization, optimizes cellular levels of oxygen for osteoblast and fibroblast proliferation, stimulates collagen formation, and supports in growing blood vessels. All of which enhances the healing potential in irradiated compromised tissues [201, 216]. HBO alone or in combination with surgery appears to be the gold standard for treatment of ORN in irradiated patients [208]. However, in the advanced stage of ORN (stage 3) the response to the treatments may be inadequate. The resection and the reconstructive surgery for the involved jaw require for the management of the stage 3 ORN. HBO should be considered as an adjuvant therapy for the treatment of ORN other than a standard of care where there is no possible access both economics and availability. Thus, it should be considered as an adjuvant therapy for the treatment of ORN other than a standard of care [47, 208].

The use of HBO is recommended in the following situations; when the post radiation radiographic reveals a poor trabeculae pattern of bone in the surgical area, the vascularization and density pattern are poorer when compared to the pre-radiation radiograph, in the patient who has comorbid diseases such as diabetes, hematologic profile or the extracted teeth are in the field of radiation.

If extensive wounding or tooth extraction in radiation portals is necessary, then HBO treatment should be used both prior to surgery and after wounding occurs [216]. Treatment with antioxidants and antifibrotic drugs may be helpful in the case that ORN is of fibroblastic origin [191]. The real value of HBO in prevention and treatment of osteoradionecrosis still has to be established in randomized controlled clinical trials.

Dental Caries

Dental caries is a lifetime threat to the patients who had radiation to the head and neck region. It is mainly an indirect effect of irradiation induced changes in salivary gland tissue that result in hyposalivation, altered salivary composition, a shift in oral flora toward cariogenic bacteria (*S. mutans*, *Lactobacillus* species), and dietary changes. The caries development caused by two mechanisms:

The first is that radiation damaged either partly, or totally of the salivary glands caused a major complication of xerostomia, which lead to nearly total cessation of salivary secretion. The saliva defense mechanisms were diminished due to a reduction in oral wash out; the capacity of food clearance from the oral cavity was affected as well, particularly the sugary and acidic food that are defined as cariogenic food. In addition, salivary proteins that inhibit cariogenic microorganisms and electrolytes that buffer oral acids are decreased resulting in remarkably increased proportions of cariogenic pathogens; *S. mutans* and *lactobacilli* [217-219]. In subjects with radiation-induced hyposalivation, caries incidence increases rapidly [220-221].

Secondly, radiation has the direct effect on the teeth to make them more susceptible to decalcification, and damages the pulp, gradually dries the dentine and makes it brittle, which leads to easy loss of enamel from the dentinoenamel junction (Figure 4) [46, 54]. In addition, the sensation of dryness or difficulty with chewing and swallowing leads the patients to change their preference to softer food which may be more cariogenic. They may need to frequent sip drinks or beverages that contain sugar in order to keep their mouth moist.

The decay process usually occurs in the first year following radiation therapy. It is likely to occur more quickly in teeth which have a large amount of root cementum exposed and those with poor hygiene presenting with large amounts of plaque formation. However, the incapability of maintaining the high standard level of oral hygiene aggravates the carious conditions which can rapidly develop within a few weeks after radiotherapy [217, 220].

Radiation caries are predominantly at the tooth cervical, however, the incisal edges and cusp tips are also at risk. Within 1 to 2 years, the development of rampant caries could be observed in the radiated patients and frequently found as devastating destruction of teeth with fracture of crown to gum level (Figure 5) [39, 54, 222].

The Control and Prevention of Dental Caries

It is now generally accepted that caries prevention can be achieved in irradiated patients by the daily use of fluoride in conjunction with meticulous oral hygiene and strictly adherence to a non-cariogenic diet. There are many fluorides products that contain either sodium fluoride, acidulated phosphate fluoride or sodium monofluorophosphate available for professional application as well as for home use in a variety of vehicles, including gels, rinses, lozenges and chewable tablets. However, the disadvantage of these preventive procedures is often by poor compliance of patients. Fluoride varnishes can be used to provide longer exposure to fluoride and may be useful for the prevention of caries associated with xerostomia. Prevention of hyposalivation will invariably contribute to the prevention of

radiation caries with the use of artificial saliva preparations, remineralizing mouth rinse solutions. Placement of sealants is also beneficial. The use of disclosing agent for dental plaque is also constructive for oral hygiene procedures [35, 36, 39, 217, 222].

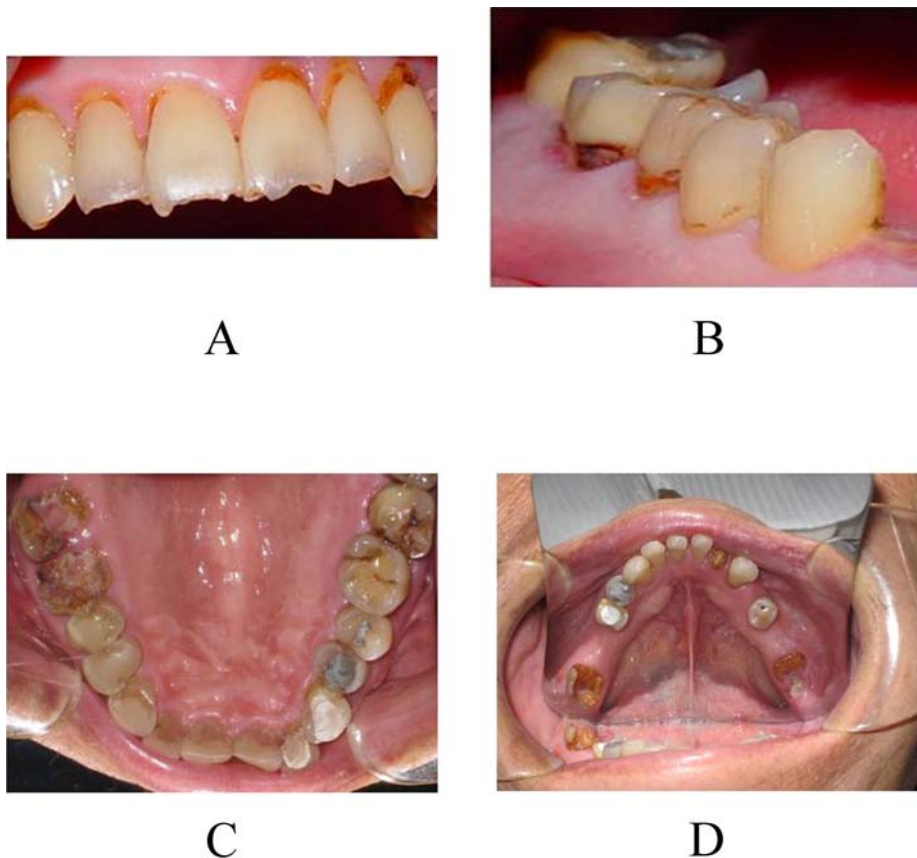


Figure 5. Radiation caries at the incisal edges and cusp tips (A), at the tooth cervical (A, B, C), destruction of teeth from caries with fracture of crown to gum level (C, D).

Neurotoxicity and Teeth Hypersensitivity

Neurotoxicity and teeth hypersensitivity is common post-radiation neuropathy (sensory or motor) following the treatment of HNC. With the high doses from 62.5-100 Gy, they may develop within 1-10 years after treatment [223]. Mucosal pain of radiation induced severe mucositis may persist for up to one year, which indicates that this long-term impact may be related to epithelial atrophy and neuropathic mechanisms [223]. The combination of chemoradiotherapy is also generally related with painful mucositis and neurotoxicity. It is reported that certain classes of chemotherapeutic agents can cause direct neurotoxicity and relate to leukemic infiltration of dental pulp tissue and direct jaw infiltration. The patients may have deep seated, throbbing mandibular pain and dental hypersensitivity which may occasionally occur weeks or months after chemotherapy [43]. However, coincident occurrence of pain in cancer patients can be observed according to other conditions non-

related to cancer such as toothache, temporomandibular disorders (TMD), sinusitis, headaches, and occasionally herpes zoster [64].

Management of neurotoxicity is supportive treatment for pain. Topical fluoride application and desensitizing toothpaste may improve the discomfort [43].

4. Periodically Assessment (Recall)

Since the risk of disease recurrences and the adverse effects of treatments are common, a close follow-up is required. Some complications may require a lifetime of management and the consequences may cause some damage that turn out in permanent dysfunction. As such, surgical treatment of malignancies in the oral cavity often result in an unfavorable oral condition, *e.g.* palatal fistulas which require prostheses rehabilitation such as denture and obturator. A protocol of follow up is essential for the prevention or reduction of the incidence of late complications such as dental caries, xerostomia, and osteoradionecrosis.

The dentist should establish a dental recall schedule for periodical check up. The assessment of the oral hygiene and existing dental care status is necessary. Preventive and supportive care should be provided, including the patient's education and symptom management through periodically oral examinations. In order to achieve optimal long term maintenance of oral health, the patients should be encouraged to perform daily plaque control and must attend the recommended recall appointments regularly. Meticulous plaque removal is important for optimal oral health; however, compliance with recommended supportive appointments is more important especially for those who cannot perform adequate oral care. Frequently recall is important for the encouragement of oral hygiene care and early detection of oral diseases and cancer recurrence. A period of 3 months is recommended, however, the more frequent can be done according to the actual needs of the individual. The patients with contributing risk factors may require supportive intervals more frequently than 3 months [224]. The regular dental check up and cleaning is essential part of life-long preventive protocol [44, 46].

Oral Care after Cancer Treatment

After radiotherapy, the biological potential for healing of the periodontium (alveolar bone, periodontal ligament, cementum) is decreased. However, in patients who had good maintenance of oral hygiene and regular application of topical fluoride, the risk for development of periodontal disease and consequently, ORN is minimized [41, 44, 45, 225, 226]. Optimal oral and periodontal hygiene must be maintained indefinitely. After initial recovery from radiation effects, non surgical periodontal therapy is appropriate for teeth retained in the radiation field, despite with prophylactic antibiotics coverage [44].

Management of carious teeth: after radiation the conservative treatment is preferred. Tooth restorations should be simple and render the acceptable esthetics and functions. Full coverage crowns and splints are ineffective in the patients with xerostomia since it is difficult to clean especially at the cervical margin which is vulnerable to recurrent caries [54]. Ideally,

restoration materials used in the xerostomia patients should have fluoride release and be cariostatic. Light-activated glass-ionomers seem to be the suitable because of extension fluoride release and fluoride uptake in the dry oral environment, esthetics and greater resistance to acid attack and dehydration as well as the tooth adhesion. The dental amalgams are recommended on occlusal surface of posterior teeth and the use of conventional glass-ionomer cement base since fillings with composite resin have higher risk of marginal leakage and recurrent caries underneath the restorations. In children routine restoration treatment must be delayed until the patient is in remission [46, 54].

Endodontic treatment remains a practical treatment alternative for post radiation therapy especially for the infected pulp if the tooth is restorable. However, avoiding pushing debris beyond the apex when doing the instrumentation, and shorter endodontic fillings are recommended. Periapical radiolucencies may persist after successful endodontic treatment due to decrease alveolar vascularity and hypocellularity. Endodontic therapy in the poor prognosis case just because the risk of ORN from extraction should not be attempted. There were several severe cases of ORN reported from an improper case selection of endodontic treatment [47].

Tooth extractions in irradiated area have been considered as major risks factors for the development of ORN. Some authors suggested avoiding post-radiation extraction of teeth in radiation fields for prevention of ORN [50]. However, if the extraction cannot be avoided, it can be performed within a five- to six-months window of tissue repair and healing. This, prior to the irradiation induce onset of progressive fibrosis and loss of vascularity following the treatment completion; provided, the patient must not suffer from an acute effect of the radiation such as mucositis [49]. This healing phase is a much safer time to undertake necessary extractions, and HBO is usually not needed. The risk of ORN does not diminish with time. The longer the clinicians wait, the lesser the healing capacity, and the greater the risk of ORN [46]. Tooth extraction should be performed with minimum mucoperiosteal flap and alveoloplasty and also in an atraumatic approach. Antibiotics coverage before and after extraction is strongly recommended [36, 205, 207]. Bone exposure after extraction should be treated conservatively such as using local saline irrigation with an occasional use of oral antibiotics [47, 50].

It is recommended that the patients who had teeth extracted immediately before radiotherapy wait at least one year before wearing dentures [46]. The patients who already had dentures before radiation should have them reevaluated since the newly environment such as xerostomia or scar fibrosis may affect the dentures fitting. The soft liners may be helpful. A study concluded from the clinical assessment that the patients could benefit from an implant-retained mandibular denture [72].

An obturator may be necessary in the patient who has palatal defect in order to maintain the oronasal function in the cases with small size palatal fistulas. However, the poor fitting obturator can bring many negative consequences such as pain, injury of the mucosal edge and ulcer as well as the poor hygiene. The large palatal fistula the surgical repair is recommended [227].

Conclusion

The oral assessments and dental care prior during and after cancer treatments are important so as to eliminate predisposing factors of trauma and infections, which lead to more severe oral complications. Palliative and conservative treatments are still the choice of care together with meticulous maintenance of oral hygiene and the conjunctive use of topical chemotherapeutic agents applied such as topical fluoride, anti-plaque agents application. Through good oral hygiene, the incidences and severity of oral complications are significantly reduced, especially the oral infections. In contrast with the bacterial plaque accumulation and gingivitis, pathogenic organisms may disseminate systemically and cause more risk of septicemia. The patients should therefore be motivated to keep their mouths very clean. Periodically oral assessments and care should be carefully continuous performed after cancer treatment for life long.

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Chapter 3

Advances in Paediatric Restorative Dentistry

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Abstract

Dental caries has been a highly prevalent and costly disease in the world, representing the most common infectious disease in the paediatric population. Caries lesions are also increasingly isolated in specific teeth and tooth morphology types, and there is growing controversy about the most appropriate restorative material for these lesions in deciduous teeth. In fact, restorative materials continuously improved in durability, strength, aesthetics, and anti-cariogenic properties. Moreover, the increasing demand for aesthetic restorative treatment has totally transformed the practice of paediatric dentistry in the last decade. Traditionally, the use of amalgam was a standard procedure in the restoration of carious primary teeth. Because of the introduction of adhesive restorative materials, the treatment of proximal caries has changed. The principal advantage of these new materials is that they require less retention form and this is particularly important in primary teeth to conserve the relatively thin enamel that could help prevent subsequent carious invasion of dentin.

When planning dental treatment for paediatric patients, each subject and restorative material to be used should be evaluated on an individual basis, in order to provide appropriate care within each material's limitations. This chapter reviews the evolution of restorative materials used in paediatric dentistry, from the amalgam to bonding materials. The current trends and future directions in material research are also discussed. The chemical composition and the physico-chemical properties of the following materials are reported: Amalgam; Stainless steel crown restorations; Pit and fissure sealants;

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Dentin/enamel adhesives (from the first to the seventh generation); Glass-ionomer cements; Resin-based composites; Compomers. In order to assist the practitioner in the restorative dental care of children and adolescents, the clinical use and the cost-effectiveness of the various materials currently used in paediatric restorative dentistry are also discussed, with a special focus on the dentin/enamel adhesives.

Introduction

Dental caries has been a highly prevalent and costly disease in the world, representing the most common infectious disease in the paediatric population. The disease is also increasingly isolated in specific teeth and tooth morphology types in both primary and mixed dentitions, with pits and fissures being the predominant diseased sites. Caries risk is greater for children who are poor, from a rural setting, from an ethnic minority or who have limited access to care [1]. Factors for high caries risk include a number of decayed/missing/filled surfaces superior to the age of the child, numerous white spot lesions, high levels of *Streptococcus mutans*, low socioeconomic status and/or level of parental education, high caries rate in siblings/parents, diet high in sugar, presence of dental appliances, high levels of infection with cariogenic bacteria, impaired ability to maintain oral hygiene, malformed enamel or dentin, reduced salivary flow because of medications, radiation treatment or disease, and low salivary buffering capacity [2, 3]. Studies have reported that caries in the primary dentition is highly predictive of caries occurring in the permanent dentition, and that maxillary primary anterior caries has a direct relationship with caries in primary molars [4, 5].

Restorative treatment shall be based upon the results of an appropriate clinical examination and ideally should be part of a comprehensive treatment plan, which should consider developmental status of the dentition, caries-risk assessment, the patient's oral hygiene, anticipated parental compliance and likelihood of timely recall, the patient's ability to cooperate for treatment [6, 7]. Moreover, the restorative treatment plan must also be prepared in conjunction with an individually tailored preventive program.

Restoration of primary teeth differs significantly from restoration of permanent teeth, partly due to the differences in tooth morphology. However, the materials used in paediatric restorative dentistry are commonly the same as those used in restorative dentistry in general.

For many years, stainless steel crowns (SSCs) and silver amalgam were commonly used for the primary dentition. However, with an increased use of adhesive restorative materials and bonding systems, there has been a shift to a more conservative treatment. Moreover, the increasing demand for aesthetic restorative treatment has totally transformed the practice of paediatric dentistry in the last decade. Materials such as glass-ionomers, resin ionomer products, and improved resin-based composite systems have been developed which are having a profound impact on the restoration of primary teeth, particularly the treatment of proximal and anterior caries. The principal advantage of these new materials is that they require less retention form and this is particularly important in primary teeth to conserve the relatively thin enamel that could help prevent subsequent carious invasion of dentin.

This chapter reviews the evolution of restorative materials used in paediatric dentistry, from the amalgam to bonding materials, and provides information on the clinical use and the

cost-effectiveness of the restorative materials. The current trends and future directions in material research are also discussed. Original papers, reviews and current guidelines on this subject, published in English from 2002 until 2008, were located in the MEDLINE/Pubmed database. Additional publications were obtained by searching the reference lists of retrieved studies.

1. Amalgam

Silver amalgam has been used for restoring teeth for over 150 years and it is still used extensively in paediatric dentistry. Ease of manipulation, durability, relatively low cost, and reduced technique sensitivity compared to other restorative materials are all properties of amalgam that have contributed to its popularity. However, the improvement in the physical and aesthetic properties of the restorative materials, together with the continuing concern over the toxicity of dental amalgam, have led to a decrease in its use.

1.1. Composition and Properties of Amalgam

Dental amalgam consists of an alloy of silver, copper, tin and zinc combined with mercury. The un-reacted alloy particles are called Gamma Phase, which are mainly silver-tin. These particles combine with mercury forming a matrix consisting of Gamma 1 and Gamma 2 Phases. Gamma 1 Phase involves the binding of silver and mercury (Ag_2Hg_3), while Gamma 2 Phase involves the binding of tin and mercury (Sn_7Hg). Gamma 2 Phase is responsible for early fracture and failure of amalgam restorations.

Copper was introduced to avoid the Gamma 2 Phase, replacing the tin-mercury phase with a copper-tin phase (Cu_5Sn_5). The copper-tin matrix decreased the corrosion of tin, preventing secondary weakening with subsequent fracture of the restoration [8].

Creep is a dimensional change that occurs when amalgam is submitted to a load, as in mastication, and is the result of the visco-elasticity of the material. To be certified, the American Dental Association (ADA) requires that an amalgam should have a maximum of 5% creep [8].

1.2. Concerns Related to Use

Toxicity of Amalgam

The potential toxicity of mercury is the main concern regarding the use of dental amalgam. Even if encapsulation of the silver/tin alloy and mercury reduces the risk of inhalation, concern still persists relating mainly to the effects of: (1) inhalation of mercury vapour or amalgam dust; (2) the ingestion of amalgam, (3) allergy to mercury, and (4) environmental considerations [9].

Inhalation of Mercury Vapour by Dental Personnel

Dental personnel have been found to excrete greater amounts of mercury in the urine than a control population. These resulted from poor mercury hygiene, and, in fact, it has been demonstrated that, after they responded positively to advice in the correct handling of mercury and amalgam, there was a fall in the excreted mercury in the urine of dental personnel [9].

Ingestion of Amalgam by Patients

Inhalation and ingestion of mercury from dental amalgam can occur during placement, polishing, removal of restorations or during chewing. The daily dose of mercury from dental fillings, produced by chewing, would appear to amount to 1-2 µg/adult. The threshold for hazard to health from air/mercury exposure in the general population is 5 µg/m² air, while it is 1 µg/m² for children and pregnant women. All estimates of the daily total amalgam-associated mercury intakes are well toxicity below thresholds [9].

Mercury can also pass from mother to foetus, and may be detected in the milk. However, one human study demonstrated that the correlation between mercury levels in the mother and the newborn child was more closely related to the amount of fish consumed than to the number of amalgam fillings in the mother. Moreover, animal and human studies have not demonstrated any association between amalgam fillings and birth defects [9]. Furthermore, plasma and urine mercury levels following placement or removal of restorations can be considerably reduced when the rubber dam is used [10].

Allergy to Mercury

Allergies to amalgam are rare [9]. Hypersensitivity tests revealed that some, but not all, were due to copper or silver. There have been reports of an association between some oral lichenoid lesions and the presence of amalgam fillings adjacent to the affected area of the oral mucosa. Removal of the restorations is only recommended if there is clear contact between the restorations and the lesion. It should be kept in mind that other restorative materials can also cause lichenoid lesions [11].

Environmental Issues

The use of mercury in dentistry accounts for about 3% of the total amount used worldwide. Several European countries have encouraged good mercury hygiene in dental practices, including proper handling of waste amalgam to prevent it from reaching the environment [9, 12].

1.3. Clinical Use

Treatment of caries should meet the needs of each particular patient, based on his/her caries risk. For small occlusal lesions, a conservative resin restoration, using composite or compomer in conjunction with the sealant, would be more appropriate than the classic Class I amalgam preparation, when the tooth can be appropriately isolated.

For proximal lesions, amalgam would be indicated for 2-surface Class II preparations that do not extend beyond the line angle. This recommendation might not be appropriate for

restoring first primary molars in children aged 4 and younger. If the carious lesion is extensive and/or in more than 2 surfaces, a stainless steel crown (SSC) would be suitable, even for children older than 4 years.

Although SSCs are recommended when pulpotomized primary teeth are restored, Class I amalgam can be an appropriate restoration when the remaining walls are thick enough to withstand the occlusal forces and natural exfoliation is expected within 2 years or less [13].

Moreover, today a number of alternatives to amalgam challenge the continued use of this material in children.

The dental literature [14] supports the use of amalgam in the following situations:

1. Class I restorations in primary and permanent teeth;
2. two-surface Class II restorations in primary molars where the preparation does not extend beyond the proximal line angles;
3. Class II restorations in permanent molars and premolars;
4. Class V restorations in primary and permanent posterior teeth.

2. Stainless Steel Crowns

Preformed metal crowns for primary molar teeth, more commonly known as the SSCs in the United States, were first described in 1950. The crowns are much easier to place and often require minimal modifications from their manufactured form.

The SSC is extremely durable, relatively inexpensive, subject to minimal technique sensitivity during placement and offers the advantage of full coronal coverage. Its main disadvantage is its appearance. In primary teeth, the SSC finds application following pulpotomy/pulpectomy and is applicable for teeth with developmental defects, large carious lesions involving multiple surfaces where an amalgam is likely to fail, and fractured teeth. In permanent teeth, the SSC can be used as an interim restoration for a broken-down or traumatized tooth and for teeth with developmental defects. The SSC's benefits of durability and full coverage for a relatively low cost are not available from other restorative materials, and for all of these previously cited indications in both primary and permanent teeth, the decision to place an SSC is the best practice.

SSCs can be suitable for the restoration of not only posterior teeth, but also anterior ones in cases where multiple surfaces are carious, where there is incisal edge involvement, following pulp therapy, when hypoplasia is present, and when there is poor moisture control [15].

Several brands of primary SSCs are available with preformed tooth-coloured veneers. Although the crowns are much easier to place and often require minimal modifications from their manufactured form, these veneered SSCs can be more difficult to adapt and are subject to fracture or loss of the facing.

2.1. Longevity and Cost-Effectiveness

Several clinical studies comparing SSCs with amalgam restorations in primary molars demonstrated evidence of the clinical effectiveness of treatment with SSCs over amalgam restorations, including the multi-surface ones [16-20]. The risk of caries in the child, age at time of treatment, and longevity of the individual restoration all impact cost and treatment-outcome effectiveness of the materials chosen to restore the primary dentition [21]. Three papers [22-24] have dealt with the cost-benefit of SSC vs amalgam, and all reported that SSCs were more cost-effective than amalgams for primary molar teeth. Use of a well-fitting SSC, where appropriate, could be expected to lengthen the longevity of the primary tooth and, in some cases, permit the tooth to last a lifetime [25].

2.2. Use of SSCs in Primary Molars

The primary molars are very important teeth, in fact they have the function of maintaining space for the permanent successors and contributing to the growth and development of the face and jaws. When proximal caries is restored with a material subject to failure, this function can be compromised and these children may require orthodontics to regain lost space and accommodate the permanent teeth or need to use a stainless steel crown.

According to the literature, the current indications for use of SSCs for primary molar teeth are as follows:

- after pulp therapy;
- for restorations of multi-surface caries and for patients at high risk of caries;
- primary teeth with developmental defects;
- where an amalgam is likely to fail (eg, proximal box extended beyond the anatomic line angles;
- fractured teeth;
- teeth with extensive wear;
- abutment for space maintainer [26-28].

2.3. Use of SSCs in Permanent Molars

The literature also supports the following indications for use of SSCs for permanent molar teeth:

- interim restoration of a broken-down or traumatized tooth until construction of a permanent restoration can be carried out or the eventual orthodontic status is established;
- when financial considerations are a concern, permanent SSCs are useful as a medium-term economical restoration in clinically suitable cases;

- teeth with developmental defects. The crowns are beneficial for restoring the occlusion and reducing any sensitivity caused by enamel and dentin dysplasia in young patients;
- restoration of a permanent molar which requires full coverage but is only partially erupted [26, 29, 30].

3. Dentin / Enamel Adhesives

Dentin/enamel adhesives have revolutionized restorative dental practice during the past 40 years. Adhesives are used mainly in paediatric dentistry to bond resin-based composites and compomers to primary and permanent teeth. More conservative cavity preparations can be performed, maintaining more tooth structure when the adhesives are used with composites and compomers. However, meticulous care in the placement of adhesives, resin-based composites and compomers is necessary to produce long-term satisfactory results.

The principles of adhesive dentistry date back to 1955 when Buonocore reported that acids could be used to alter the surface of enamel to “render it more receptive to adhesion” [31]. Enamel bonding has been widely and successfully used in dentistry for over 40 years, while dentin bonding has been possible only during recent decades. A wide assortment of dentin/enamel adhesives is currently available on the market. The practicing paediatric dentist should carefully evaluate the available scientific evidence about clinical performance to choose the appropriate system for practical use.

3.1. Dentin/Enamel Adhesives: From First to Seventh Generation

First Generation

First generation systems were introduced by Bowen in 1965 [32]. N-phenylglycine and glycidyl methacrylate (NPG-GMA) are the principal agents. The bond strengths of these early systems were only 1 to 3 megapascals, therefore the clinical results with these systems were poor [33].

Second Generation

In the late 1970s, the second generation systems were introduced, containing bisphenol-A glycidyl methacrylate (bis-GMA), or hydroxyethyl methacrylate (HEMA). These systems bonded to dentin through an ionic bond to calcium by chlorophosphate groups. Even if these systems were a significant improvement on first generation systems, they showed a weak bond to dentin. In fact, the phosphate bond to calcium in the dentin was not strong enough to resist the hydrolysis resulting from water immersion. This hydrolysis could result in composite resin debonding from the dentin and causing microleakage. Thus, to tackle this inconvenience, third generation systems were introduced [33].

Third Generation

With the third generation systems of the 1980s, the acid etching, i.e. 17 percent ethylenediaminetetraacetic acid (EDTA) or 2.5 percent maleic acid, partially removes and/or

modifies the smear. The acid opens dentinal tubules partially and increases their permeability. The etching must be rinsed completely before the primer is applied. Dentin primers may be 6 percent phosphate penta-acrylate (PENTA), 30 percent HEMA, and 64 percent ethanol. The primers contain a hydrophilic group that infiltrates the smear layer, modifying it and promoting adhesion to dentin, and the hydrophilic group of the primer creates adhesion to the resin. Following etching and primer application, the unfilled resin adhesive is applied to dentin and enamel. However, a weak bond to dentin has been determined by the partial removal of smear layer [33].

Fourth Generation

The complete removal of the smear layer is achieved with fourth-generation bonding systems of the early 1990s. One of the main characteristics of these systems is the “total-etch technique”, which permits the etching of enamel and dentin simultaneously using 40 percent phosphoric acid for 15 to 20 seconds [34].

When the dentinal tubules are completely opened, this allows the formation of an intermingled layer of collagen fibres and resin called the “hybrid layer”, “resin-reinforced zone” or “resin-infiltrated layer”. This hybrid layer, which was first described in 1982 by Nakabayashi et al. [35], has been considered the most important factor for ensuring a good bond between resin and dentin. The hybrid layer was defined as “the structure formed in dental hard tissues (enamel, dentin, cementum) by demineralization of the surface and subsurface, followed by infiltration of monomers and subsequent polymerization”. In addition to hybrid layer, the formation of resin tags and adhesive lateral branches complete the bonding mechanism between the adhesive material and etched dentin substrate [36].

The mineralized tissues of the peritubular and intertubular dentin are dissolved by acidic action, with consequent exposition of collagen fibres. In order to avoid the collapse of these fibres and promote the opening of dentinal tubules, the “wet bonding technique” was introduced, which consists in leaving the dentin moist, after its conditioning [37]. Because the etch/prime/bonding adhesives require multiple applications, there are numerous opportunities for errors to occur [38]. Therefore, manufactures have attempted to simplify the systems by reducing the bonding steps and thus, the working time [33].

Fifth Generation

The fifth generation of bonding systems was developed during the mid 1990s to make the use of adhesive materials more reliable for the practitioner. This generation consists of two different types of adhesive materials: the “one-bottle systems” and the “self-etching primer” bonding systems.

“One-bottle systems” combined the primer and adhesives into one solution to be applied after etching enamel and dentin simultaneously (the total-etch/wet-bonding technique) with 35 to 37 percent phosphoric acid for 15 to 20 seconds [39]. These systems show high bond strength values both to etched enamel and dentin [40].

Self-etching primers combine the acid etching and the primer in one step, reducing the working time, eliminating the washing out of the acidic gel and also eliminating the risk of collagen collapse. However, the self-etching primer solution also has some disadvantages. In fact, the solution must be refreshed continuously because its liquid formulation cannot be

controlled where it is placed, and often a residual smear layer remains between adhesive material and dentin. Moreover, the effectiveness of self-etching primers on properly etching the enamel was less predictable than the result obtained with phosphoric acid gel [39]. Bond strength tests often did not demonstrate statistically significant differences between one-bottle systems and self-etching primer bonding systems [33].

Sixth Generation

The sixth generation of adhesive materials was introduced in the late 1990s and early 2000s, with a one-stage mechanism composing two components. Etching depth and bonding resin penetration depth is identical, forming chemical and mechanical bonds. The simple packaging of these systems, i.e. two components in two bottles only, may be problematic because imperfect mixing could cause decreased adhesion strength.

In fact, the first evaluations of these systems showed a sufficient bond to conditioned dentin while the bond with enamel was less effective [33]. This may be due to the fact that these materials are composed of an acidic solution that cannot be kept in place, must be refreshed continuously and has a pK that is insufficient for properly etching enamel.

Seventh Generation

In late 2002, several bonding systems were proposed as the seventh generation of adhesive materials, with a one-stage mechanism consisting of one component: etchant, primer and adhesive are in a single bottle. The process of sixth and seventh bonding generation is similar, but the seventh generation has one component, thus avoiding any errors in mixing. The strength of adhesion to dentin is very high, and three subsequent applications in 30 seconds have enabled deeper resin penetration into dentinal tubules [41]. Bonding resin bond to dentin depends on the penetration of bonding resin into smear layer and on the depth of bonding resin penetration into the dentinal tubules.

Premature loss of bond strength is one of the problems that still affects adhesive restorations reducing their durability. Endogenous matrix metalloproteinases (MMPs) may be partially responsible for hybrid layer degradation [42]. According to the most recent literature [43], chlorhexidine might be useful for the preservation of dentin bond strength by inhibiting MMPs.

Chlorhexidine has been widely used in dentistry as an antimicrobial agent, also for disinfection before the placement of restorations. Previous studies have demonstrated that chlorhexidine application prior to acid-etching has no adverse effects on immediate restorative material-adhesive bonds in dentin [44-46] and enamel [45, 47]. The antimicrobial efficacy of chlorhexidine used as a preparation disinfectant has been questioned when the surface is subsequently conditioned [48]. Recent studies examined the use of chlorhexidine after acid-etching and all of them demonstrated initial bond strengths comparable with those of the controls [46, 49,50].

3.2. Bonding to Primary Teeth

The literature suggests differences between primary and permanent teeth regarding the composition and morphology of the dentin [51]. For example, primary dentin has even greater regional variation than permanent dentin, and has been described as containing more, and in some cases unusually large, dentinal tubules [52]. Much less is known about the performance of dentin adhesives in primary teeth than in permanent teeth, also because primary teeth are difficult to obtain in sufficient quantities for research. Studies with earlier generations of adhesive systems routinely reported lower bond strengths to primary than to permanent dentin [53]. However, studies on total-etch adhesives have revealed similar bond strengths to both types of dentin [54].

3.3. Clinical Use

Although the dental market continually introduces new bonding systems, no product is “perfect”, each has its own particular strengths and weaknesses. The ideal bonding system should be biocompatible, bond indifferently to enamel and dentin, have sufficient strength to resist failure as a result of masticatory forces, have mechanical properties close to those of tooth structures, be resistant to degradation in the oral environment and be easy to use for the clinician.

Tooth bonding adhesives were found to be effective in enhancing retention, minimizing micro-leakage, and reducing sensitivity, and their use in primary restorative dentistry is currently supported by the dental literature [55]. Moreover, today the simplicity of using these bonding systems and the reduction of the clinical times, which by the last generation of adhesives allow, represent valuable advantages in restorative treatment of paediatric patients. Further research is needed in order to evaluate the clinical efficacy of these adhesive systems in primary teeth.

4. Pit and Fissure Sealants

Sealants are materials which are designed to prevent caries in occlusal, buccal and lingual pits and fissures. They are introduced into the occlusal pits and fissures of caries-susceptible teeth, forming a micromechanically-bonded protective layer, cutting access of caries-producing bacteria from their source of nutrients. Pit and fissure caries account for approximately 80% of all caries in young patients, also in fluoridated communities [56].

Susceptibility to caries on tooth surfaces containing pits and fissures is related to the form and depth of these pits and fissures. Two main types of pits and fissures are usually described: 1) shallow, wide V-shaped fissures that tend to be self-cleansing and somewhat caries resistant, and 2) deep, narrow I-shaped fissures that are quite constricted and are highly susceptible to caries [57].

High-risk pits and fissures should be sealed as soon as possible. In fact, the plaque accumulation and caries susceptibility are greatest during the eruption of the molars. Low-

risk pits and fissures may not require sealants. Caries risk, however, may increase due to changes in patient habits, oral microflora, or physical condition, and subsequently unsealed teeth might benefit from sealant application [58].

Arrest of caries and elimination of viable organisms have been demonstrated under sealants or restorations with sealed margins [59]. Paediatric dentists often incorporate enameloplasty into the sealant technique as in vitro studies suggested that it may enhance retention of sealants [60, 61]. However, short-term clinical studies show enameloplasty as equal to but not better than sealant placement without enameloplasty [62, 63].

Isolation is a key factor in a sealant's clinical success. Contamination with saliva results in decreased bond strength of the sealant to enamel. Studies incorporating recall and maintenance have reported sealant success levels of 80% to 90% after 10 or more years [64, 65].

4.1. Types of Pit and Fissure Sealants

Resin

Resin-based fissure sealants are bonded to the underlying enamel using the acid etch technique. The resin sealants may be either pure resin, composites or compomers, and their polymerization may be initiated chemically or by light.

Several studies reported the effectiveness of second generation chemical initiated sealants [66-68].

Ripa [69] reviewed numerous studies that have been carried out to compare the retention rates between sealants. The results indicated that the performance levels for chemical initiated sealants and visible light photoinitiated sealants were similar within an observation period of up to 5 years. However, in three comparison studies of longer duration, greater longevity was reported for the chemically cured pit and sealants [70-72].

Resin-based sealants are available as clear, opaque or tinted. The last two sealants have the advantage of more accurate evaluation by the dentist at recall [73]. Several studies have shown that resin sealants are able to stop further progression of carious lesions in pits and fissures, and even in dentine lesions [74, 75], because the placement of sealants isolates the carious lesion from the surface biofilm. This suggests a therapeutic use for sealants in addition to a preventive one.

Glass-Ionomer Cements (GICs)

One of the main clinical advantages of GICs is their ability to bond chemically to dentine and enamel without the use of the acid-etch technique [76], which makes them less vulnerable to moisture. This, in conjunction with fluoride release into the surrounding enamel [77], has led to the development and evaluation of GIC as an alternative sealant system, particularly in cases where moisture control is difficult to achieve.

Studies on the use of GICs [78-80] and resin modified glass-ionomers [81] as sealants indicate significantly lower retention rates than resin based ones. However, several studies have found that GICs exert a cariostatic effect even after they have disappeared

macroscopically, and that this effect might be based on remnants of the cement in the fissure as well as increased levels of F on the enamel surface [82-84].

The use of GICs has been suggested for erupting teeth where isolation is a problem, especially in the high caries risk individuals. In this situation they can be considered more of a fluoride vehicle than a traditional sealant. However, GICs were traditionally not recommended for use as sealants due to brittleness and susceptibility to fracture under the occlusal forces developed during mastication. However, there are instances where glass-ionomer sealants could be considered appropriate as an interim preventive material for occlusal surfaces before molars are completely erupted.

Fluoride Containing Sealants

The durability of fluoride containing sealants would now appear to be comparable to conventional resin sealants [85, 86]. However, further long-term clinical trials are necessary to determine that the clinical longevity of sealants retention is not adversely affected by the presence of incorporated fluoride. Also, the clinical importance of the fluoride ion in fluoride-containing sealants in terms of caries prevention remains to be shown.

4.2. Clinical Technique for Resin Sealants Application

Step 1: Isolate Tooth Surface from Salivary Contamination

Ideally, the tooth should be isolated from salivary contamination using rubber dam isolation. Cotton roll isolation with adequate suction to remove saliva from the operating field is also acceptable and is the preferred method of isolation for many practitioners, particularly in the partially erupted teeth or when treating children whose cooperation is poor.

Step 2: Cleanse Tooth Surface

The need for surface cleaning prior to sealant placement may seem controversial. Raadal et al. [87] suggest careful removal of plaque and pellicle using pumice or air-polishing instruments in order to obtain optimal acid-etch pattern of the enamel, while Harris and García-Godoy [88] maintain that the effect of acid etching alone is sufficient for surface cleaning provided obvious soft material has been removed. The literature on the efficiency of different cleaning procedures on bonding is extensive, including the use of rotating burs in order to remove superficial enamel and opening the fissure in order to let the resin penetrate [73]. Although cleaning the fissures with a bur has given superior retention in some studies [63, 89], there is evidence in other studies that it provides no additional benefit [90]. Furthermore, purposeful removal of enamel or enameloplasty just to widen the base of a fissure in a sound tooth is an invasive technique which disturbs the equilibrium of the fissure system and unnecessarily exposes a child to the use of a handpiece or air abrasion. It is concluded, therefore, that there is a need for removal of most organic substance in order to obtain sufficient bonding, but that the removal of sound tooth tissue using instruments such as burs is unnecessary and undesirable.

Step 3: Acid-Etch Tooth Surface

Apply the etching agent to the tooth surface with a fine brush, a cotton pledget, or a mini-sponge using the manufacturer's recommended exposure time. Exposure time varies from 15 seconds for permanent teeth to 15 to 30 seconds for primary teeth [58, 91] with additional etching time for fluorosed teeth. The most frequently used etchant is orthophosphoric acid with a concentration between 30% and 50% by weight.

Step 4: Rinse and Dry-Etched Tooth Surface

The tooth is usually irrigated vigorously with air and water for about 30 seconds and then dried with uncontaminated compressed air for 15 seconds [92]. The dried, etched enamel should have a frosted-white appearance. If the enamel does not have this appearance, repeat the etching step. If salivary contamination occurs at this stage, repeat the etching process.

Step 5: Apply Sealant to Etched Tooth Surface

Apply the sealant material to the etched tooth surface and allow the material to flow into the pits and fissures. With auto-polymerizing sealants, working time varies from 1 to 2 minutes. With photoactivated sealants, the setting reaction is initiated by exposing the sealant to visible light and usually requires 10 to 20 seconds for complete setting.

Step 6: Explore the Sealed Tooth Surface

Explore the entire tooth surface for pits and fissures that may not have been sealed and for voids in the material. If deficiencies are present, apply additional sealant material.

Step 7: Evaluate the Occlusion of Sealed Tooth Surface

Evaluate the occlusion of the sealed tooth surface to determine whether excessive sealant material is present and must be removed.

Step 8: Periodically Re-Evaluate and Reapply Sealant as Necessary

During routine recall examination, it is necessary to re-evaluate the sealed tooth surface for loss of material, exposure of voids in the material, and caries development. The need for reapplication of sealant material is usually highest during the first 6 months after placement.

4.3. Cost-Effectiveness of Sealants

Tooth surfaces with pits and fissures are particularly vulnerable to caries development and derive benefit from systemic or topical fluoride. Sealants can prevent caries and are generally considered cost-effective [93].

However, it is also recognized that the cost-effectiveness is dependent on some factors that are related to its use, e.g. the caries prevalence in the population, the different tooth types (premolars, molars) sealed, whether all teeth and fissure sites are routinely sealed or based on specific indications, the retention of the sealant, and to what extent other caries preventive methods are used (e.g. fluoride varnish). Since 1995, it has been recommended that the sealants should not be routinely used in all children for all teeth, but based on individual risk evaluation [94].

The effectiveness of sealants is increased with good clinical technique, appropriate follow up and resealing as necessary.

4.4. Clinical Use

Sealants may be used to prevent caries in teeth thought to be at risk, or to arrest the progression of caries lesions limited to enamel.

The dental literature [58, 95] supports the following recommendations for use of sealants:

1. Susceptible sites of primary and permanent teeth can be sealed depending on assessment of risk factors.
2. Children and young people with signs of acute caries activity: all susceptible pit and fissure sites should be considered for sealants, including the buccal fissures of permanent molars.
3. Children and young people with no signs of caries activity: only deeply fissured teeth should be considered for sealing.
4. The choice between resin/composite and glass-ionomer sealants should be based on adequacy of moisture control. As the resins are the most durable they should generally be preferred, while GICs should be used in cases where moisture control is difficult, e.g. in erupting or newly erupted teeth. GIC sealants in these cases are regarded more as a temporary sealant or a fluoride release vehicle, rather than a true sealant.
5. Where there is real doubt about the caries status of a susceptible site on clinical examination, e.g. a stained fissure, then a bitewing radiograph should be obtained. If there is unequivocal evidence that the lesion is confined to enamel then the surface can be sealed and monitored clinically and radiographically.
6. If the lesion extends into dentine after removal of staining, then a sealant restoration ("preventive resin/GIC restoration") may be used. A more extensive cavity requires a conventional restoration.
7. All sealed surfaces should be regularly monitored clinically and radiographically. Bitewing radiographs should be taken at a frequency consistent with the patient's risk status. The exact intervals between radiographic review will depend not only on risk factors, which may change over time, but also on monitoring of other susceptible sites, for example proximal surfaces.
8. Defective sealants and/or preventive resin or GIC restorations should be investigated and the sealants reapplied in order to maintain the marginal integrity, provided the surface is caries free.

5. Glass-Ionomer Cements

GICs were developed by Wilson and McLean at the Laboratory of the Government Chemist in England in 1965 [96]. They were a logical addition to the family of water-based dental cements, comprising silicate cement, zinc phosphate cement and zinc polycarboxylate cement. Since their commercial introduction, they are now available in essentially two types. “Conventional” glass-ionomers consist of a fluoroaluminosilicate glass, usually a strontium or calcium salt, and polyalkenoic acid liquid, for example polyacrylic, maleic, itaconic and tricarballic acids. The conventional materials derive from an acid-base reaction between the acidic liquid and the basic powder. More recently, in order to improve the physical properties and decrease the water sensitivity of the conventional materials, the so-called “resin-modified GICs” have become available. These contain a polymerisable resin, commonly hydroxyethylmethacrylate (HEMA), and therefore have the additional setting reaction of resin polymerization, which may be self-cure and/or light-cure. The significant properties of the glass-ionomers are adhesion to calcified tooth structure, release of fluoride, minimal effect on the pulp, and that they are tooth-coloured. However, they are sensitive to dehydration early in the setting process, particularly the conventional cements, and they are brittle materials and therefore unsuitable for use in load-bearing areas. In view of these properties, they have a wide range of uses, including fissure sealants, anterior approximal restorations, cervical restorations (both carious and non-carious), in deciduous teeth, as lining and luting cements, and as orthodontic band and bracket materials.

Due to importance of fluoride in preventive dentistry, GIC systems can be considered therapeutic materials. Fluoride ions are not only released by glass-ionomers, but are also taken up by associated enamel and dentin, rendering those tooth structures less susceptible to acid challenge by a combination of decreased solubility and disruption of bacterial activity that produces organic acids [97, 98].

Glass-ionomer materials have been shown to be able to release fluoride at a sustained rate for long periods of time (at least 5 years) [99]. Also, as water-based systems, they act as continuing fluoride ion reservoirs in the mouth by taking in salivary fluoride from dentifrices, mouthrinses, and topical fluoride solutions at the dental office [100]. The fluoride ion dynamic is particularly advantageous for those with high susceptibility to dental caries.

Another application of GICs where fluoride release is beneficial is for the atraumatic restorative technique (ART) [101]. ART utilizes hand or rotary instruments for the removal of carious tooth structure, with the placement of a GIC to restore the tooth. ART was developed for caries treatment in children where resources were not available to provide traditional care. ART may be used to restore and prevent dental caries in young patients, uncooperative patients, patients with special health care needs, and situations where traditional cavity preparation and placement of traditional dental restorations is not feasible.

5.1. Clinical Use

The dental literature [102] supports the use of GIC systems in the following situations:

1. Luting cement:
 - a) stainless steel crowns;
 - b) orthodontic bands;
 - c) orthodontic brackets (limited).
2. Cavity base/liner.
3. Class I restorations in primary teeth.
4. Class II restorations in primary teeth.
5. Class III restorations in primary teeth.
6. Class III restorations in permanent teeth for high-risk patients or teeth that cannot be isolated.
7. Class V restorations in primary teeth.
8. Class V restorations in permanent teeth for high-risk patients or teeth that cannot be isolated.
9. Caries control:
 - a) high-risk patients;
 - b) restoration repair;
 - c) ART.

5.2. Recent Developments In GIC Systems

Clinical research has produced scientific evidence that resin-modified GIC systems are durable and reliable when used within their limitations in primary and permanent teeth [103].

The latest advancement in glass-ionomers is a “nano-ionomer”. The glass filler formulation of this nano-ionomer makes for a resin-modified glass-ionomer material with high polishability, enhanced tooth shade-matching potential, and better physical properties. Nano-ionomer is recommended for primary teeth restorations, interim repair of all permanent teeth, relatively confined Class I restorations, Class III and Class V tooth repair, and certain core build-ups [104, 105].

6. Resin-Based Composites

Resin-based composites represent one of the most widely used contemporary restorative materials. They have some advantages, such as excellent aesthetic qualities, low thermal conductivity, preservation of tooth structure in cavity preparation, and advances in the stability of compositional properties of the material.

6.1. Composition and Properties

Conventional resin-based composites were viscous fluid involatile monomers (BIS-GMA) that have filler particles incorporated into the resin. Many contemporary composite restorative materials contain dimethacrylate monomers (BIS-GMA) as the major component of the matrix phase. A relatively low-viscosity monomer (triethylene glycol dimethacrylate, TEGDMA), which helps produce the desired handling qualities of the material, is an important component of the matrix phase.

Filler particles are incorporated into the monomer matrix. A small number of available products contain urethane dimethacrylates rather than the BIS-GMA matrix. The fillers were coated with a vinyl silane coupling agent, the silane chemically bonding with the polymer matrix.

These particles were usually irregularly shaped to provide mechanical retention in the resin. Composites available today contain quartz, colloidal silica, borosilicate glass, and glass containing barium, strontium, and zinc. Excluding quartz and colloidal silica, these filler particles give the material radiopacity, which is clinically advantageous during radiographic examination.

Contemporary posterior resin-based composites contain a high percentage of filler particles by volume. This composition provides resistance to wear and greater stability. Thermal expansion and polymerization contraction are both reduced by increasing the volume percentage of filler particles.

6.2. Classification

Resin-based composites are classified according to the polymerization process and filler size.

Polymerization Process

Chemically polymerized resin-based composites are commercially available in two components. Usually, the benzoyl peroxide present in one paste acts as the initiator, whereas in the other paste a tertiary amine (dihydroxyethyl-p-toluidine) acts as the catalyst. These materials form cross-links during copolymerization of methyl methacrylate and ethylene glycol dimethacrylate. The dimethacrylate monomers polymerize, by means of free radical-initiated polymerization, to form the organic matrix of a three-dimensional network [106].

Today most resin-based composites are visible light-activated materials. They usually contain a diketone initiator (camphorquinone) and an amine catalyst (dimethylaminoethyl methacrylate). The advantages of this type of composite include ease of manipulation, more control of their placement into a cavity preparation, no need for mixing and control of polymerization. The polymerization of visible light-activated resin-based composites is affected by 4 factors: 1) the constituents of the resin-based composite material, 2) the configuration factor of the cavity preparation, 3) the spectral distribution and power of the visible light-curing unit, and 4) the clinician's technique. As polymerization proceeds, there is a change in state from a viscous liquid to a solid, resulting in shrinkage [107].

Volumetric shrinkage and filler loading play an important role in the contraction stress of composite material. Configuration factor, or C-factor, is the ratio of the bonded area of the restoration to the unbonded area. The higher the C-factor, the greater the stress will be on the bonded surfaces. It is thought that a high C-factor stress can be partially compensated by using of flowable composite material [108]. These materials, recently introduced in the market, have a wide range of filler loadings to suit many clinical indications, and are easy to handle and place in a cavity due to their flow characteristics [109, 110]. The application of a flowable composite prior to placement of the resin composite might function as an elastic liner as well as preventing gap formation at the internal margin [111]. Recently, visible light-curing unit manufactures have attempted to decrease the amount of contraction stress by introducing curing lights that initially have a low intensity and/or a short duration of cure (soft cure techniques). It is thought that this slower set permits movement of the polymer chains, allowing stress relief and improved marginal integrity. Some authors reported positive results with the soft cure techniques, whereas others did not find significant effects on marginal integrity [112-114].

Filler Size

Filler size affects polishability/aesthetics, polymerization depth, polymerization shrinkage, and physical properties.

Macrofilled resin-based composites, developed in the 1960s, have fillers that range from 10 to 100 μm . These were the first products called traditional or large-particle resin-based composite.

Microfilled resin-based composites were introduced in the 1970s with an inorganic filler particle size averaging less than 0.1 μm .

A thorough classification system, which classifies composites by the size of their filler particles, was developed [115].

Midsized-filled (also called midifil, fine or small particle) particles range from 1.0-10 μm . This particle size provides greater strength than a microfilled composite and better polishability than a macrofil one.

Minifilled (also called, all-purpose, submicron, or microfine) particles range from 0.1-1.0 μm . These restorative materials were still relatively stronger and more polishable than midifilled ones. Most modern posterior resin-based composites use a combination of particle sizes to achieve superior strength and improved aesthetics over traditional macrofills. In the 1980s, hybrids containing midsize (1.0-10 μm) or minifilled (0.1-1.0 μm) particles and 7%-15% microfilled (<0.1 μm) particles began to be used in posterior load bearing surfaces [116]. The heavy filler loading (50%-70% by volume) possible with hybrids provided the strength and wear resistance for Class I and Class II restorations [117]. Today, minifilled (all-purpose, submicron, microfine, or micro-) hybrids are the most popular, because they can be used in anterior and posterior teeth since they are available in a variety of shades and a range of translucencies and opacities, providing excellent aesthetic properties. Although minifilled hybrids have superior strength, compared to most microfills, the latter still have better polishability. The minifilled and midifilled particles commonly contain silicate glass with metals, such as barium, strontium, zirconium, aluminium, ytterbium, boron, zinc and fluoride.

Barium, strontium, zirconium, boron and ytterbium provide most of the radiopacity of resin-based composites.

6.3. Clinical Use

The use of resin-based composites is a critical component of paediatric restorative dentistry. Tooth isolation to prevent contamination is a critical factor, and high-risk children may not be ideal candidates for resin-based composite restorations. Important factors to consider during composite placement are isolation, polymerization shrinkage and extent of restoration. When utilized correctly, resin-based composites can provide excellent restorations in primary and permanent dentition.

The dental literature [118] supports the use of resin-based composites with the following indications and contraindications.

Indications

For all resin-based composite restorations, teeth must be adequately isolated to prevent saliva contamination. The dental literature supports the use of highly filled resin-based composites in the following situations:

- a) small pit and fissure caries where conservative preventive resin restorations are indicated in both primary and permanent dentition;
- b) occlusal surface caries extending into dentin;
- c) class II restorations in primary teeth that do not extend beyond the proximal line angles;
- d) class II restorations in permanent teeth that extend approximately one-third to one-half of the buccolingual intercuspital width of the tooth;
- e) class V restorations in primary and permanent teeth;
- f) class III restorations in primary and permanent teeth;
- g) class IV restorations in primary and permanent teeth;
- h) strip crowns in primary and permanent dentition.

Contraindications

- a) where a tooth cannot be isolated to obtain moisture control;
- b) individuals needing large multiple surface restorations in the posterior primary dentition;
- c) high-risk patients that have multiple caries and/or tooth demineralization, exhibit poor oral hygiene and compliance with daily oral hygiene, and when maintenance is considered unlikely.

7. Compomers

Since 1993, the year of their introduction to the market, compomers (polyacid-modified resin-based composites) have become popular and are currently recommended for use as a paediatric restorative material in anterior and posterior teeth [119, 120]. Numerous studies [121-123] reported that the materials are acceptable in paediatric restorative dentistry.

These materials are currently considered a cross between resin-based composite and GIC. Chemically, they derived from a combination of a filler, which is formed by particles of glass-silica-strontium, and an inorganic material, like this one present in resin-based composites, with a matrix formed by polyacrylic acids and resin polymers. They also contain initiators and stabilizers of reaction.

Compomers offer advantages compared to resin-based composite and GIC. In fact, in addition to release of fluoride and adhesion to dental tissues, they have better final physical resistance, characteristics of colour and brilliance. Moreover, the long-term characteristics of compomers are less desirable than those of resin-based composites, because of lower strength and higher rates of wear.

Compomer restorations should be used in patients with low-to-moderate caries risk, and after placement the restorations should be monitored carefully to avoid complications, which could be produced by recurrent caries and wear. A minimum amount of compliance is still mandatory in order to allow for a few minutes of adhesive pre-glass treatment of cavities without contamination. If this is not the case, compomer use makes no sense, and GIC seems to be appropriate temporary restoration until better compliance can be obtained [124].

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Chapter 4

Evidence-Based Decision Making - Implications for Dental Care

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Abstract

Restorative and prosthodontic dental care refer respectively to fixing or to replacing teeth. Whether the dentist intervenes to fill cavities, produce crown or fixed bridges, or engages in the extraction of the affected dental structures and the replacement with some kind of prosthetic device, such as dentures or implants, was largely dependent, until recently in the traditional model of dental care, on sound diagnostic principles, expressed patient needs and wants, and the dentist's expertise. The novel model of dental care that has become increasingly established in the first few years of this new Century is one that strives to complement the former model by a strong reliance on the consensus obtained from all of the best available evidence. By being grounded on systematic reviews and meta-analyses of the entire body of evidence for any clinical case encountered, dental care now evolves and establishes itself as an evidence-based clinical science *par excellence*.

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This chapter reviews and discusses the fundamental elements of evidence-based decision-making in dental care. It contrasts the implications and applications of evidence-based dental care for restorative and prosthodontic services, by presenting specific clinical examples for special target populations (e.g., tooth decay in the elderly). It concludes with a set of practical suggestions for dentists seeking to be at *à l'avant garde* of this movement, and establish their practice as providing sustainable clinical solutions in the context evidence-based decision-making in dental care.

Keywords: Evidence-Based Decision-Making in dental care, restorative dentistry, prosthodontic dentistry, Level of evidence vs. Quality of the evidence, Individual Patient data vs. meta-analysis.

I. Fundamentals of Evidence-Based Dental Care

a. Models of Dental Practice

Dentistry and dental treatment modalities continue to evolve from the inception of dentistry as first conceptualized by Fauchard¹ as a domain of the health sciences in its own right 280 years ago this year. Three time periods might serve to describe this process of evolution (Figure 1), the first lasting close to two thirds of this time span, the second lasting about 50 years, and the last contemporary period having been launched in the last decade of the XX Century. The latter, now poised to carry us into the next decades, is the focus of this chapter.

¹ *Le chirurgien dentiste (The Surgeon Dentist)* was first published in Paris in 1728 by Dr. Pierre Fauchard (1678 – 22 March 1761) as the first ever compendium of basic oral anatomy & function, oral pathology signs & symptoms, operative methods for removing decay and tooth restoration, periodontal disease and manifestations associated with pyorrhea, orthodontics, as well as prosthodontic techniques including replacement of missing teeth and tooth transplantation. Fauchard has since then been regarded as the father of modern Western dentistry and dental care. Fauchard's treatise was followed in the US by Dr. Chaplin A. Harris' work close to a century later (*The Dental Art, a Practical Treatise on Dental Surgery*, 1st Ed, 1839). It is of interest to our discussion of the role of evidence vs. hear-say in the diagnosis, prevention and treatment of dental conditions, that Fauchard was among the first to reject the theory that worms cause tooth decay. He observed that sugar, which was arriving from the New World as a first rate commodity, was detrimental to the teeth structure and the surrounding gingiva. By the 1850's, the widespread availability of sugar cane, refined flour, bread, and sweetened tea corresponded with a staggering rise in the prevalence of pit and fissure caries: diet was taken as the culprit of dental caries. But, by the turn of the century, with the rise of Pacini's microscopic anatomy and Koch's bacteriology, W.D. Miller observed that bacteria inhabited the oral cavity, and that they could produce acids capable of substantive damage of tooth structures when in the presence of fermentable carbohydrates (i.e., the glycolytic process by which glucose, fructose, and most commonly sucrose are metabolized into acids, such as lactic acid); the etiology of dental caries shifted from the diet to a "chemoparasitic" model, soon confirmed by the studies on plaque and tartar by Black and Williams. In 1921, the experimental and clinical work of Major FE. Rodriguez Vargas, then on staff at the Army Dental Corps, began to establish the current (evidence-based, we could say) view of dental caries as a disease caused by specific bacteria (cf., Suddick, Richard P & Harris NO. Historical Perspectives of Oral Biology: A Series. *Crit Rev Oral Biol Med*, 1990, 1:135-151).

The emergence of dental care, as envisioned by Fauchard and his followers for the better part of two centuries, took the form of manipulations aimed at countering the ills consequential to poor oral health and little or no oral hygiene.

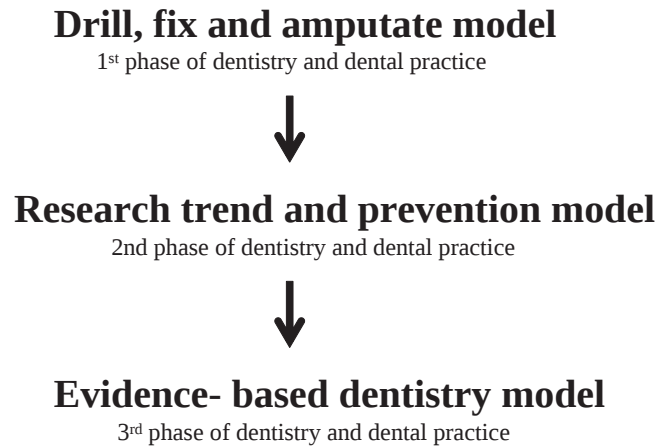


Figure 1. Models of Dental practice

Stemming from a “drill and fix” reparative mode, the primary goal of dental care was to repair damaged or decayed dental structures, or, when all else failed, to perform extractions – often, by today’s standards, wanton extractions. Some have suggested that this early stage of the profession ought better be described as a “drill, fix or *amputate*” model.

Research in physiology and medicine was nascent by the late XIX Century. Paul Ehrlich was honored with the Nobel Prize in medicine and physiology in 1908 for his characterization of what he first termed the “magic bullet”, and that today we recognize, in immunology as antibodies. Ehrlich transformed our conceptualizations of health and pathology, and of the processes by which disease could be conquered and health regained. The “trend” of research soon entered the dental field, and the “drill and fix” approach was shaken at its base as dentists began to ask – rightly so – what the fundamental mechanisms of tooth decay were, whether or not these events themselves could be countered, or even prevented. Research yielded successful observations with respect to the protective nature of sealants (at least, we know now, for certain populations, at certain ages; cf. Reeves et al, 2006) and of water fluoridation (except, that is, for subjects at-risk of fluorosis). Research advances in hygiene revealed that simple behaviors and habits of oral hygiene could be very beneficial from the perspective of preventing not only tooth decay, but a variety of oral infections, abscesses and related pathologies. A second great period of dental care had emerged and soon became recognized as the “prevention” model. It remained well established for several decades (Martin, 2004).

The value-added of this model was that it integrated specific benchmark measures that included the patient dental exam and history, and the dentist’s expertise and training, not only with utility indices, such as cost, risk, overall benefits, and, as insurance coverage grew, cost modalities, but also, and especially, with novel research evidence. It was not long before

some prided themselves to follow this model of dental care as “dentistry based on the evidence”.

Critical research mounted. Increasingly, research evidence provided newer and more detailed characterization of basic molecular, genomic and epigenetic regulation, of biochemical pathways and cellular responses, and in turn of fundamental physiologic and ultimately pathological processes. Novel “magic bullets”, drugs, materials and medicaments were developed, tested *in vitro*, in animal models, with control human subjects, and eventually in full-scale clinical trials. Evidence mounted in support of this or that intervention; but often evidence was contradictory and the clinical recommendations muddled.

The sheer amount of new research evidence called for articulated guidelines by which the new information could be identified, evaluated, and synthesized into some form of a consensus of the *best available* evidence for the purpose of revising clinical practice guidelines. Patients, now empowered by the Internet to gain access to knowledge about their condition, began to come to the dentist fully prepared to discuss one treatment approach over another, based on the research evidence to which they had access. Insurance companies monitored closely the evolution of revised clinical practice guidelines based on the best available evidence, because of its critical role in utility-based clinical decision-making and treatment repayment. From a phase of emphasizing prevention, dentistry – and medicine as well, in fact – became drawn to the model on preserving or restoring wellness based on the totality of the best available evidence. Dental care emerged, as recently as the 1990’s, into its third and current period of “evidence-based dentistry” (Steele, 2000; Anderson, 2005; Chiappelli, 2008).

As practiced today, evidence-based decision-making in dental care incorporates a plethora of well-articulated information about

- the patient:
 - dental and medical history
 - wants and needs
 - exam results, symptoms and laboratory tests
- the dentist:
 - training and expertise
 - better clinical judgment based on experience
- utility concerns:
 - risk/benefit ratio
 - cost/benefit ratio
 - insurance coverage
- research evidence:
 - consensus of the best available research evidence following systematic reviews and meta-analyses
 - revised clinical practice guideline

Table 1. The four pillars of Evidence-based decision making

Patient	History, wants/needs, examination, laboratory results, etc.
Dentist	Training, expertise, clinical judgment based on experience, etc.
Utility concerns	Risk/benefit ratio, Cost/benefit ratio, Insurance coverage, etc.
Research evidence	Consensus of best available evidence derived from systematic reviews, and leading to revised Clinical Practice Guidelines

Effective evidence-based decision-making for dental practice in our modern society rests on these firmly established four pillars, summarized in Table 1, below: should one be undervalued, clinical intervention would be undermined and sub-adequate dental care would ensue.

That said, it is essential to recognize the three fundamental limitations of the evidence-based dentistry model:

- Firstly, it is inappropriate to expect that evidence-based dental practice is an “all-purpose bag”, a “fit-all glove”, a “shoe-in” for every and all cases in clinical dentistry: the fact of the matter is that it is not. It is a tool, a tool that pertains specifically and uniquely to certain situations, and that cannot be adapted to others. It is as inappropriate to try to force the evidence-based paradigm in every clinical situation, as it was to extract wantonly teeth as a standard of dental care 150 years ago. Dentists must be trained to recognize when the evidence-based model of care is appropriate, and when it is not.
- Secondly, it is inappropriate to expect that all the graduates from established, accredited professional dental programs will be equally trained in evidence-based dental care, and capable to discern when this model is recommended, how should systematic reviews and meta-analyses outcomes be processed into revised clinical practice guidelines, and to what extent the latter should come into play to modify and update patient utility considerations of cost, coverage benefit and risk. As a matter of practical fact, they are not: they are clinicians first and foremost – not researchers².
- The “dentist/scientist” model, opined, proposed and defended by the National Institutes of Health (NIH) and the American Dental Association (ADA), states that, by definition, dentists-scientists would be trained and willing to distribute professional expertise and activities equally between research and practice. This perspective is far from being a reality. But, it is precisely the dentist/scientist who would be best prepared to run an evidence-based dental practice. Therefore, the need

² If they have research training and a degree, they tend to gravitate either toward an emphasis on clinical practice (if they hold a Master’s degree), or toward dental research and academia (if they hold a doctoral degree). Rarely, will they balance their professional activities equally between clinical and research responsibilities, as the model of the clinical dentist/scientist was intended to mandate.

for dentists/scientists trained in evidence-based decision-making is all the more critical and timely³.

In brief, over the past three centennials, we have witnessed a metamorphosis in the practice of dental care. From its onset in the early 1700's, dentistry has been driven by at least four distinct forces:

1. the patient's symptoms, fears, needs and wants,
2. the provider of dental care's training, expertise and best clinical judgment,
3. financial considerations of cost and insurance coverage, compounded with treatment risks and benefits, and
4. the strength of research evidence.

We noted above that, as the science of oral biology and medicine became increasingly established, the understanding of the fundamental mechanisms of oral pathologies and dental conditions became more widely disseminated. "Magic bullets" for treatment and interventions were developed and tested, and research evidence for clinical outcome went from being the exception to being the norm. Modern dental care demanded that this evidence be integrated in the clinical decision making matrix. As evidence multiplied, the establishment of strict norms for evaluating the type and quality of the research evidence was deemed essential for attaining the optimal goal of integrating the best available evidence in dental care.

It remains that the criteria for evidence-based clinical decision-making in dental care must be established. It is not sufficient simply to note that providing dental care today goes beyond single individual pieces of research, but that rather is based on a concerted process of evidence-based research by which, given a clinical case, the entire body of pertinent published research is collected, evaluated for the level and quality of evidence, and for its overall meta-analytical significance. It is simplistic to assert that the conclusive inference from these analyses yields an overall consensus of the pertinent research evidence, which serves to revise clinical practice guidelines, as they refer specifically to the starting clinical case. It is correct, yet overly academic and theoretical to support that, in its fundamental conceptualization, evidence-based dentistry is translational research *par excellence*.

What is truly needed is "to turn the corner". What we must work toward is for evidence-based dental care is to empower the dentist with at least two fundamental skills:

1. to be able to discern when the evidence-based dental care approach is pertinent to a clinical case, and when it is not; and
2. to have the ability to extract from the available information the necessary criteria of *best available evidence* for performing evidence-based dental practice

³ One optimal instrument to attain this goal ought to be a Federally-supported professional Master's degree training program in evidence-based dental care.

b. History of Evidence-Based Decision-Making

The evidence-based model of dental practice is more recent than its counterpart in medicine. The latter originated from the work of Dr. Archibald Cochrane (1909-1987) in the 1970's. The British epidemiologist analyzed the impact of research in clinical intervention and decried the inability of the medical profession to make the best use of experimental results for the benefit of patients (Cochrane, 1971, 1989). Then followed seminal publications from the Department of Clinical Epidemiology and Biostatistics of McMaster University, Canada, which signified the birth of modern evidence-based medicine, and evidence-based health care. They consisted in a series of position papers on systematic critical strategies on how to read critically the medical literature. This work flourished into graduate students' theses and dissertations at McMaster, and was soon echoed and expanded in the American and British medical literature. This activity was seminal in establishing the means by which the research literature ought to be interpreted efficiently for the benefit of clinical situations and clinical decision-making. The establishment of the Cochrane group, based in Manchester, for the generation of critical reviews of the research literature – hence known as systematic reviews – soon followed in the 1980's (cf., Chiappelli, 2008). The Cochrane Oral Health Group⁴ held a 2-day international Symposium in May 2006 to celebrate the first decade of their collaborative work for the implementation of research evidence in dental practice.

The work *ex novo* in evidence-based dentistry began in earnest when the American Dental Association (ADA) Board of Trustees examined this new approach to clinical practice and dental care, and adopted resolution (B-18-1999) in February 1999. The widely adopted resolution defined evidence-based dentistry as:

“an approach to treatment planning and subsequent dental therapy that requires the judicious melding of systematic assessments of scientific evidence relating to the patient's medical condition and history, the dentist's clinical experience, training and judgment and the patient's treatment needs and preferences”.

As important a turning point that statement was, it further resolved:

- that a task force be convened to determine the Association's role in evidence-based dentistry as it relates to patient dental care,
- that this task force be comprised of two members of the ADA Council on Scientific Affairs – this strengthened and emphasized at the very onset of the movement the scientific nature of evidence-based dentistry,
- that one member each from the ADA Council on Dental Benefit Programs, Council on Dental Practice and Council on Access, Prevention and Interpersonal Relations be appointed to the task force, which established the contribution of insurance coverage and utility factors, dental care and clinical expertise, as well as the public health

⁴ Cochrane Oral Health Group, MANDEC, School of Dentistry, University of Manchester, Higher Cambridge Street, Manchester M15 6FH, UK (Tel: +44 (0) 161 275 7818; Fax: +44 (0) 161 275 7815). Review Group Coordinator (E-mail: emma.tavender@manchester.ac.uk). For a list of Cochrane reviews on the topic of dental care, see <http://www.cochrane.org/reviews/en/topics/84.html>

dimension of access to care and prevention to the multidisciplinary nature of evidence-based dentistry⁵, and

- that the task force report its findings to the Board of Trustees on a regular basis, to ensure the oversight of the professional establishment.

Clearly, 1999 can be set as the year of the official emergence of this field, and it is appropriate to discuss what has been achieved for its establishment world-wide across the profession, and what limitations remain. As a starter, the ADA had recommended:

1. That the Association survey dentists, dental schools and dental students to investigate priority clinical issues to be addressed by evidence-based dentistry research, and that this information be used to further develop the Association's Research Agenda and, through partnerships with agencies conducting evidence-based research in dentistry, to ensure evidence-based research in dentistry remains clinically relevant.
2. That the Association report to its members the latest evidence-based dentistry reviews conducted by extramural research agencies in ways that will be useful to them in clinical practice and that the Association use, and the ADA Publishing Company (ADAP-CO) be urged to use existing media (e.g., the Journal of the American Dental Association, JADA, ADA.org, continuing education courses, annual sessions, etc.) to communicate the latest developments in evidence-based practice to dentists and students.
3. That the Association explore the feasibility of the Association serving as a clearing house for information on evidence-based dentistry.
4. That the Association study the advisability of urging dental schools to include the concept of evidence-based dental practice and evidence-based research in dentistry in dental school curricula.
5. That the appropriate agencies of the Association place on their 2000 agendas the issue of evidence-based dentistry as it relates to their respective areas of responsibility.
6. That the Council on Scientific Affairs convene a meeting of two members from each of these agencies to be held in Chicago in the Summer of 2000 to share information on evidence-based dentistry and develop further recommendations for Association action to submit to the Boards of Trustees.

Unquestionably, the usefulness of this position statement by ADA, the premier professional association for dental care provider, signified the birth and establishment of the field nation-wide and at an international scale. Staring a mere decade ago, it catalyzed the establishment of the evidence-based dentistry interest group at the International Association

⁵ within two years, we presented a seminal series of papers (Chiappelli & Prolo, 2001, 2002a: Part I & Part II) that explored the meta-construct of evidence-based dentistry, revealing the domains noted above, in addition to the psycho-societal, psycho-emotional and psycho-cognitive domains, in an concerted effort to propel evidence-based dentistry into the XXI Century (Chiappelli & Prolo, 2002b) within the context of translational research (Chiappelli & Prolo, 2003).

for Dental Research (IADR), and the emergence of two widely regarded journals dedicated the pursuit of evidence-based research and practice in dentistry, and its implications and applications to the process of clinical decision-making for the improvement of dental care. The wide and increasing readership of *Evidence-Based Dentistry* out of the Nature group, and of the *Journal of Evidence-Based Dental Practice* from Elsevier attest to rise of interest and sophistication in this realm of science. Several research, clinical and review papers were published on diverse facets of evidence-based dentistry in a variety of other journals as well, from JADA, to the *Journal of Dental Research* (JDR), to *General Dentistry* and *Quintessence*, to various specialized journals in the respective dental specialties.

The Cochrane Oral Health Group now lists over 250 systematic reviews either completed or in various stages of execution, that range from preventive dental care, to restorations, to orthodontics, to prosthodontics, and other dental specialties. Textbooks for students and established dentists alike went to press⁶, and are now enriching existing undergraduate, graduate, dental, and continuing education curricula in evidence-based dentistry. Taken together, this concerted effort over the past 10 years has undoubtedly positioned the field for full blossoming in the next decade.

However, and as laudable as the goals originally proposed by the ADA statement were, relatively few of the listed objectives have been concretely and fully met in the past timeline: still much work needs to be done to introduce, disseminate and teach evidence-based dentistry, let alone to actualize it in the clinical decision-making context of dental care. Fundamental limitations still remain, the salient of which are discussed below.

c. Issues and Limitations of the Evidence-Based Decision-Making Model

The field has been criticized as a “conspiracy” among certain insurance companies: a conspiracy aimed to control individual choice and limit professional judgment (Newman and Baudendistel, 2001) – an expression of the fear that third-party payment systems will somehow “conspire” to use evidence to limit the benefits and coverage provided by their programs (Anderson, 2001).

On the contrary, the process of making evidence-based decisions about care is about increasing the range of choice of options. Evidence-based decision-making is about giving clinicians the tools they need to apply the best evidence for individual patient needs. Evidence-based decision-making emphasizes accountability, efficiency, and minimization at worst, and elimination at best of unnecessary or harmful treatment (Anderson, 2001; Newman and Baudendistel, 2001). The goal of the evidence-based decision making in clinical dental care practice translates concretely in improved patient outcome by means of the search for, and utilization of the best available research findings.

Governmental agencies, dental societies, insurance companies, dental schools, dental manufacturers, and numerous individual practitioners have followed the leadership of A. Cochrane, the Cochrane Group, McMaster University and the ADA, and have embraced the principles of using the highest quality of research evidence for clinical treatment intervention.

⁶ cf., Chiappelli, 2008

Diverse, albeit we must underscore not all sectors of dentistry use evidence-based methods to revise clinical practice guidelines, make policy, develop insurance plans, teach students, develop new products, and treat individual patients (Newman and Baudendistel, 2001).

That notwithstanding, the debate over evidence-based dental care, in contrast to dental care based on the evidence, remains far from being abated to this date. Three main arguments are typically presented (Tonelli, 2001), and three counter-arguments recently summarized (Chiappelli, 2008):

- *dentists have relied upon reliable research evidence for their treatment ever since the rise of modern dentistry* (Tonelli, 2001). Evidence-based decision-making seeks to emphasize that research in the health sciences in general, and dental care in particular is advancing at such a fast pace that the body of evidence must be systematically evaluated and synthesized for the benefit of the patients, the providers, and society (Chiappelli, 2008).
- *in some domains of the health sciences in general, and dental care in particular, the research evidence can be deficient, inadequate, unreliable, or inexistent. Consequently, it is often the case that dental care must rest on traditional modes of interventions even if they have not been validated by research* (Tonelli, 2001). Evidence-based decision-making is grounded of the certainty that the systematic evaluation of the research methodology, designs and data analysis is all the more critical, because it is that process, safe none other when done appropriately, that uncovers research deficiencies in given clinical domains. This is key, then, to improve the quality of the research evidence in dental care (Chiappelli, 2008).
- *a grave fundamental conceptual error of the evidence-based approach consists in the drive to group knowledge derived from clinical experience and physiologic rationale under the heading of the best available evidence. This process is dangerous because it can further compound the error by developing hierarchies of evidence. The implications are drawn from that critique that lack of evidence and lack of benefit are not the same, and that the more data are pooled and aggregated the more difficult it becomes to compare the patients in the studies with the individual patient in front of the dentist. That is to say, clinicians, it is argued, need to incorporate knowledge from several distinct areas into the clinical decision making process, including empirical evidence, experience, physiologic principles, patient needs, wants and coverage, and professional values* (Tonelli, 2001). Evidence-based decision-making process consists in systematically evaluating the strength of the available evidence. It is not to group “*knowledge derived from clinical experience and physiologic rationale under the heading of the best available evidence*”, nor is it to develop “*hierarchies of evidence*” (Tonelli, 2001). Rather, the purpose of evidence-based decision-making is to generate a consensus statement of the best available evidence in the form of a systematic review of all of the available research. The systematic review that results goes beyond the routine narrative literature review: it is a systematic evaluation of all of the available research evidence – good and bad (on criteria of research design, methods and data analysis) –, which culminates in the consensus statement that is carefully crafted by a team

composed of fundamental researchers, clinicians, patient advocates, and statisticians. It is the end-product of a systematic process of critical evaluative research of the available evidence that follows the scientific method. In brief, the process of evidence-based decision-making is not aimed at pooling and aggregating data across studies indiscriminately; rather it seeks to synthesize the evidence to aid in clinical decision-making (Chiappelli, 2008).

The goal and purpose of evidence-based decision-making is unquestionably not “to compare the patients in the studies with the individual patient in front of the doctor” (Tonelli, 2001). It is to apply the best of what the research literature provides for the direct benefit of the patient (Friedland et al, 1998; Chiappelli and Prolo, 2002a and b; Chiappelli et al, 2004a; Chiappelli, 2008; Prolo et al, 2003; Chiappelli and Cajulis, 2008).

The merit and strength of evidence-based decision-making in dental care lies not only in the rigor of its scientific method, but in its product, the consensus statement, which has direct applications and extensions to the immediate needs of the patients, and the best available evidence for intervention, and the cost. A well-constructed consensus statement produces a cost-effectiveness analysis, that is a process of decision analysis that incorporates risks as well as cost (Bauer et al, 2003, 2006; Chiappelli, 2008; Merijohn, 2006).

That aside, we must not objectively ignore certain inherent weaknesses of the field that remain today (Cook et al, 1997; Robbins, 1998; Kemm, 2006; Glick, 2007; Chiappelli and Cajulis, 2008), a decade after its inception, and that will require arduous work in the next decade. The current limitations of the field of evidence-based decision-making in dental care may be summarized as follows:

- overwhelming scope of the scientific information
- high stringency of scientific research
- challenge to maintain up-dated research evaluation
- demands of clinical relevance vs. statistical significance
- different views on clinical relevance (e.g., levels of clinical significance based on categories, such as tangible vs. intangible benefits, size of treatment effect)
- subjectivity in evaluation of internal vs. external validity threats
- lack of clinical use and acceptability through clinical testing
- guarded stance at the prospect of changing and amend intervention protocols

d. Implications for Preventive and Diagnostic Dental Care - Emphasis on Restorative Dentistry and Prosthodontics

In the context of the widely accepted definition of the professional services of dentistry as the “evaluation, diagnosis, prevention and/or treatment (nonsurgical, surgical or related procedures) of diseases, disorders and/or conditions of the oral cavity, maxillofacial area and/or the adjacent and associated structures and their impact on the human body⁷”,

⁷ American Dental Association: definition adopted the ADA House of Delegates, 1997

Restorative Dentistry pertains to the domain of research and clinical endeavors of diseases of the teeth and their supporting structures, including the rehabilitation of the dentition to functional and aesthetic requirements of the individual. It encompasses the dental specialties of endodontics, periodontics and prosthodontics. The latter, one of the 9 specialties recognized by the American Dental Association, the Royal College of Dentists of Canada, and the Royal Austral-asian College of Dental Surgeons, specifically addresses the art and science of dental implants, esthetic and reconstructive dentistry for the full restoration of oral function, which may require the creation of prostheses and restorations, including complete dentures, crowns, implant retained/supported restorations. Cosmetic dentistry, implants and special designs to correct temporo-mandibular joint problems also pertain to the field of prosthodontics.

In the US, clinical standards and clinical practice guidelines⁸ dictate terms of professional ethics, training requirements, and clinical pertinence. Training includes a rigorous background in head and neck anatomy, materials science, esthetics, and occlusion, which prepares prothodontists for complex cases of full mouth reconstructions (i.e., maxillo-facial prosthetics) associated with temporo-mandibular joint disorders, congenital disorders, sleep apnea and other potentially life-threatening conditions (e.g., mouth devices used by amputees and incapacitated Veterans to aid in daily activities, tracheostomy obturators). Maxillo-facial prosthodontists also treat patients who need prosthetics in facial locations other than the stoma, such as ocular, auricular, craniofacial prostheses, and maxillary obturator prosthetics are commonly planned, fabricated, tested, applied, and evaluated by maxillofacial prosthodontists.

From the perspective of the wide domain of clinical dentistry served by this specialty, which requires the development and testing of a multitude of treatment interventions, it is not surprising that Restorative Dentistry and Prosthodontics are among the dental specialties that herald evidence-based decision-making strongly.

II. Implications and Applications of Evidence-Based Dental Care in Restorative and Prosthodontic Services

a. State of Knowledge and Available Research Systematic Reviews

We noted elsewhere (Chiappelli and Cajulis, 2008) that certain interventions in dentistry need not, or cannot be subjected to the evidence-based paradigm. Take, for example, a superficial cavity in the enamel compartment of a molar: here an aggressive restoration involving a root canal, a crown or an implant is most likely uncalled for. By contrast, carious lesions that project proximal to the pulp chamber, will, in all likelihood require aggressive restoration. In this particular case, evidence-based dental care is most probably not needed.

By contrast, in situations where a body of research evidence is extant about more than one treatment intervention, and the clinical judgment of the dentist dictates a careful

⁸ set by the American College of Prosthodontists (ACP), and the Academy of Prosthodontics (AP)

evaluation of effectiveness and efficacy of each approach, the process of evidence-based dentistry finds a critical place (Figure 2).

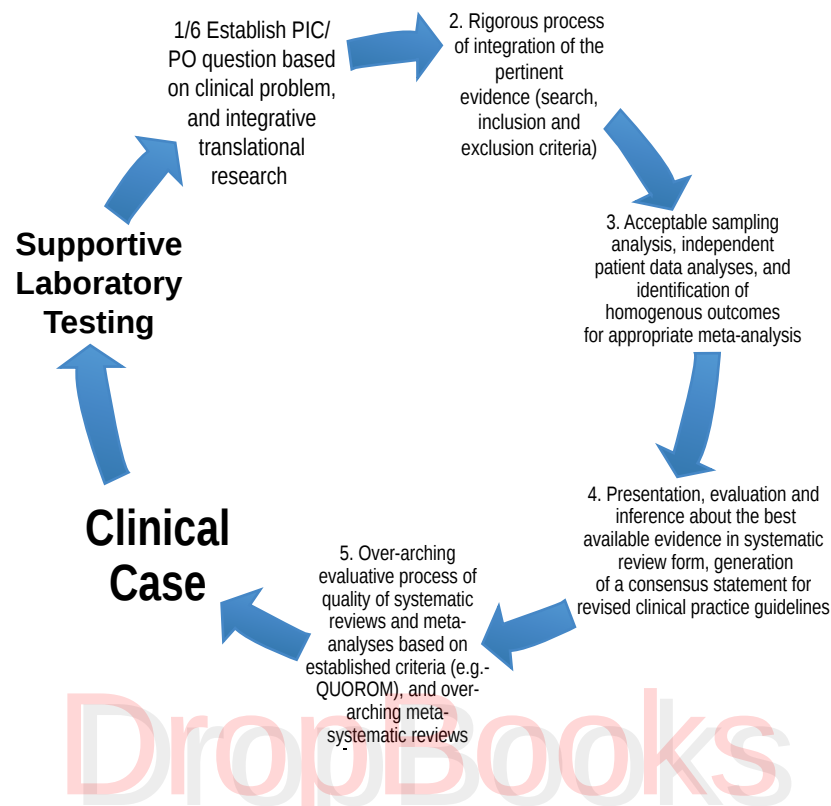


Figure 2. The Process of Evidence-Based Decision-Making in Dental Care.

The process of the systematic evidence-based evaluation of the research evidence involves generally the following, as outlined in the figure:

- whether or not the problem was framed in a clinically relevant manner (i.e., PIC/PO question), and the validity of information integrated (i.e., critical evaluation of the literature),
- the rigor of process of integration (i.e., inclusion and exclusion criteria of reliable vs. unreliable [acceptable vs. unacceptable] evidence⁹),

⁹ which would estimated by a computerized protocol that involves the principles of Boolean logic. That is to say, if, for instance, assessments for any one domain could be evaluated to be congruent and to generate a conjunctive logic association (study question =1, study outcome=1, conjunction =1). The conjunctive logic association could further the process of quality, effectiveness, and efficacy, which each could be reduced to a series of boolean arguments. The outcome would be automating the process of research evaluation in evidence-based dentistry toward a computer-assisted software (e.g., 1 = report overall acceptable based on criteria of research methods, design and analysis, 0 = report unacceptable, based on commonly accepted criteria). Zeros appear in the boolean process whenever a disjunction is attained (e.g., design in congruent for stated study question and study outcome). Both acceptable and unacceptable reports are integrated in the consensus statement. The latter contribute in formulating recommendations for the best available evidence for

- the data from separate reports are pooled, when appropriate, for meta-analysis, meta-regression, Individual Patient Data analyses (Nieri et al, 2003), and acceptable sampling¹⁰ statistics. The data are analyzed from the perspective of Bayesian modeling in order to interpret data from research in the context of statistical significance and clinical relevance, and effectiveness and utilities data are estimated (e.g., Markov model¹¹), and
- the presentation and evaluation of the quality of the findings (i.e., summative evaluation).

The outcome of this process is the generation of a consensus statement of whether, and how current clinical practice guideless ought to be revised to optimize patient benefit/risk ratio. However, these recommendations must be viewed in light of a utility-driven cost-effectiveness analysis, which yields the best benefit/cost assessment, often expressed as the incremental cost-effectiveness between conventional treatment alone and conventional treatment supplemented by complementary alternative treatments. The incremental ratio, that is the difference in costs between the two strategies divided by the difference in effectiveness between the two strategies are key indices in the evidence-based decision-making process. This will require dissemination of consensus statements in lay and foreign languages (Chiappelli et al, 2006a and b; Chiappelli, 2008).

Evidence-based decision-making for dental care relies on clinical practice guidelines revised based on the outcomes of systematic reviews. Systematic reviews differ from traditional literature reviews, in that the latter address primarily the scientific domain whereas the former is concerned with the quality of the research evidence and the overall consensus resulting from the entire body of available research¹².

clinical decision-making, whereas unacceptable reports are discussed in terms of their deficiencies and the information they may provide for further improvement of research. Evidence-based evaluations of such as these considerably enhance the value of the consensus statement, whose focus and intent is neither “to group information” (Tonelli, 2001), nor “to establish evidence hierarchies” (Tonelli, 2001), but rather it is to make a generalized, well-informed and scientifically supported statement of acceptability of any dental treatment intervention under scrutiny.

¹⁰ To obtain estimates of the data *acceptability* (Montgomery, 2000)

¹¹ This is usually achieved by means of the Markov model-based decision tree. This approach permits to model events that may occur in the future as a direct effect of treatment or as a side effect. The model produces a decision tree that cycles over fixed intervals in time, and incorporates probabilities of occurrence. Even if the difference between the two treatment strategies appears quantitatively small, the Markov model outcome reflects the optimal clinical decision, because it is based on the best possible values for probabilities and utilities incorporated in the tree. The outcome produced by the Markov decision analysis results from the sensitivity analysis to test the stability over a range probability estimates, and thus reflects the most rational treatment choice (Yu et al, 2003; Sugar et al, 2004).

¹² The Cochrane Group (www.cochrane.org), named after Archibald Cochrane (1908-1988), regarded as the father of evidence-based medicine, suggests that systematic reviews should consist of a) Background, b) Objectives, c) Methods of the review, d) Results, and e) Conclusion and discussion. The Cochrane Group also stipulates seven steps for preparing and maintaining a systematic review:

1) Formulating a problem (PICO question), 2) Locating and selecting studies (search), 3) Critical appraisal of studies (research quality assessment), 4) Collecting data (data mining for meta-analytical tabulation), 5) Analyzing and presenting results (acceptable sampling and meta-analysis), 6) Interpreting results (generation of consensus statement), 7) Improving and updating reviews (updating process so that it consistently reports the “best available” evidence). Based on that outline, several attempts are ongoing to establish criteria for the

The systematic review in dentistry is the report product of a hypothesis-driven research process by which the best available literature is critically reviewed. It centers on a single clinical question¹³, which is concerned with the specific patient population of interest, the interventions under contrast, and the clinical outcome of interest. The question leads to the sample of published and otherwise available research reports, which are evaluated for the quality of the design, methodology and data analysis. The research that is deemed acceptable is then examined in order to extract the underlying statistical trends by means of meta-analysis¹⁴, and to yield an over-arching statement of significance (Moher et al, 2002, 2007; Chiappelli, 2008).

Systematic reviews are generally regarded as the highest level of evidence¹⁵ in health science research from medicine to dentistry. An understanding of systematic reviews and how to implement them in practice is becoming mandatory for all professionals involved in the delivery of health care. The process of implementation of systematic reviews in an evidence-based dental practice model of dental care remains elusive, in part because the process by which the best available evidence can be sifted out for discordant systematic reviews is still unresolved (Jadad et al, 1997; Ismail and Bader, 2004; Lockhart et al, 2007; Machikanti, 2008).

b. Relevance of the Evidence-Based Approach to Dental Care

As noted in preceding paragraphs, evidence-based research in the health sciences is controversial for a variety of reasons that range from the perception that providing services to patients in medicine, dentistry, nursing and other health sciences has been based on research evidence for decades. Hence, there is nothing new. Alternatively, it has been voiced that if a given procedure has been performed to some degree of success for years, why bother to change, even if the best available evidence mandates that it should be discarded or updated

systematic evaluation of systematic reviews, acceptable analysis of a body of systematic reviews pertaining to the same clinical case, and the generation of meta-systematic reviews (cf., Figure 2).

¹³ The PICO question – Patient under study, Interventions being Compared, for given Outcome of interest.

¹⁴ The meta-analysis is an analytical process that combines the results of several studies that address a set of related (=“homogeneous”) research hypotheses. Meta-analysis was originally developed by Karl Pearson (1857 – 1936) in 1904, in order to overcome the problem of low statistical power in studies with small sample sizes. Modern meta-analytical techniques were developed and established by Gene V. Glass (1940 -) in 1976, and by Jacob Cohen (1923–1998) (cf., Glass et al, 1981). As their use in systematic reviews in evidence-based fields of study becomes increasingly widespread, the need is dawning for an even more powerful statistical technique: one that will permit the overarching analytical evaluation across several systematic reviews with homogenous PICO questions; that is to say, a meta meta-analysis of sorts. It is possible and even probable, when considering the very limitations of statistical stringency that such a meta-tool will have to incorporate the fisherian meta-analytical approach within the context of Bayesian analysis (i.e., to the “prior” meta-analysis will be added on the “posterior” of the newly obtained homogeneous meta-analysis for a better approximation of the “population” of outcomes) (Petitti, 1994).

¹⁵ At present, a dichotomy exists in that research reports can be evaluated in terms of *what* was done (i.e., systematic review, clinical trial, observational study, animal study, laboratory study; e.g., Sacket et al, 1996), and of *how* the study was done (i.e., quality of research design used, of research methodology [measurement, sampling, etc.], and of data analysis based on established criteria of research rigour; e.g., Stroup et al, 2000; Deeks, 2001; Moher et al, 2002; Wong et al, 2003; GRADE 2004). Optimally, systematic reviews utilize both criteria for obtaining the best available evidence (cf., Chiappelli, 2008; Machikanti, 2008).

(cf., Chiappelli et al, 2006a; Chiappelli and Cajulis, 2008; Chiappelli, 2008). This polarity is particularly evident in dentistry because of the process by which certain dental protocols have evolved into common use today.

If evidence-based research in dental care is simply to be considered as a tool, a technique, a procedural approach complementary to our profession, then prohibitively complex conceptual and practical hurdles will soon emerge that will impair, rather than optimize patient treatment. Inappropriate evaluation of the evidence and misinterpretation of the research findings will be detrimental to clinical decision-making, because they will engender ill-recommended modes of intervention. Continued misrepresentation of the field of evidence-based decision-making in dental care, its purpose and intent, and process and outcome, will do nothing more than to propagate the misconception that "*evidence-based dentistry does not work*".

For example, if prosthodontics or restorative dentistry were not considered a specialty *per se*, but were merely viewed as a set of technical skills, then undoubtedly the efficacy and effectiveness of our clinical interventions with patients with particular needs would be hindered. Clearly, we must all agree that what characterizes a specialty in the dental profession is the fact that its domains are specific and circumscribed, and do not, for the most part overlap with those pertaining to other specialties (i.e., diagnostic decision trees, modes of interventions, clinical practice guidelines). Certain decision-making criteria and intervention protocols are shared, and can be similar across specialties, but a complete overlap is unlikely, lest it obfuscates the very specificity of the domains that defines each specialty. Each specialty has distinctly its unique place in the field of dentistry: its niche in the profession with respect to its purpose, procedure, and utility to the treatment of a specific group of patients.

From the viewpoint enunciated here, evidence-based dental care is a specific approach to dentistry that is both selective and specialized, as for any other dental specialty. Our original proposition that evidence-based dentistry be recognized as a specialty of the profession in its own right (Chiappelli and Cajulis, 2008) has been met with some reticence by the older generation of dentistry academics, and overwhelmingly positively by students and recent graduates, not surprisingly. This should give greater impetus to recent curricular developments in dentistry that integrate the evidence-based paradigms (e.g., Katz, 2006).

All clinical problems in dentistry must be reliably diagnosed and treated as per the practice guidelines approved by the professional body, and that are uniquely required for the case and recommended by the specialty in whose domain the case falls. In the same vein, not all domains of clinical dentistry can be handled in an evidence-based paradigm. That is to say, to perform evidence-based dental care incorrectly or when it does not pertain, does not work - it cannot work. It will not work.

The evidence-based decision-making movement is a paradigm that is based upon the application of the scientific method for the conscientious, explicit and judicious use of current best evidence, evaluated by a systematic process of the level *and* the quality of the research evidence (cf., note 15). Thus, a consensus of the total best available evidence is obtained and utilized cogently in making clinical decisions that pertain to the dental care of each individual patient. One fundamental question remains: how do we "translate" the evidence derived from group data, as commonly obtained in research studies and further

lumped together in systematic reviews and meta-analyses, to have any degree of pertinence and direct applicability to the individual patient who is needing, at this moment, dental care intervention.

Unquestionably, the traditional fisherian statistical process of grouping data into means and standard deviation is of superlative utility for establishing group differences (e.g., t tests, analysis of variance). But, it rates rather low when one wishes to study particular individuals. The Bayesian¹⁶ approach may seem more appropriate to this pursuit *a priori*, because it can take each individual patient as an individual observation, and integrate it, as a single entity, onto the information obtained about “prior” similarly obtained single observation. However, it too falters for the purpose we now seek, because it aims at the total accumulation of the “priors” and the “posteriors” for the purpose of obtaining the true representation of the *population*. We have “lost” the individual patient again!

Individual patient data analysis (Nieri et al, 2003) may be more promising in that regard since it is a technique, which is, by design, directed to analyze individual patient data independently in the context of, and in comparison to the group’s overall behavior. It is to the analysis of the mean, what the number needed to treat¹⁷ is to the sample size and power analysis, with statistical stringency being squarely on the side of the mean and sample size, and clinical relevance being squarely on the opposite side of independent patient data analysis and number needed to treat.

That is to say, whereas individual patient data analysis yields clinically relevant observations and thus appears to lend itself to the type of information one *really* needs in the

¹⁶ Thomas Bayes (c. 1702 – April 17, 1761), British mathematician and Presbyterian minister, formulated the Bayes’ probability theorem, which relates the conditional and marginal probabilities of two random events. It estimates is the “posterior” probability given “prior” events and observations. Bayes’ conditional probability (i.e., the probability of occurrence of “posteriors” is conditional upon “prior”) contrasts in foundational principle with the frequency proposition defended by the school of Fisher (Sir Ronald Aylmer Fisher; 1890 – 1962), which assigns probabilities to random events according to their frequencies of occurrence as subsets of the whole.

It must be stressed that the fisherian views on statistics are better known to most dental care providers (cf., Jakobsen, 1998). For many not fully versed in Bayesian statistics, the concept is either foreign or generally mistaken as “assigning probabilities to scientific hypotheses by means of a process of collecting evidence that is meant to be consistent or inconsistent with a given hypothesis. As evidence accumulates, the probability of the hypothesis being proven true increases or diminishes”. By logical inference, less informed scientists suggest that the Bayesian approach serves “to discriminate between conflicting hypotheses”, which is of course only partially correct (cf., Gill J. *Bayesian Methods: A Social and Behavioral Sciences Approach*, 2nd Ed. CRC Press, 2007). The Bayesian perspective on probability and perspective, while it is by all standards optimal in the evidence-based context of clinical science, remains controversial for several reasons, one being the lack of familiarity of the general public, including many scientists and clinicians due to the fact of poor or no exposure during the formative years. Others obstacles to Bayesian thinking were well articulated in a recent specialized publications, and can be summarized as 1) Bayesian methods are too often presented as an automatic inference engine, which obviously raises suspicion in anyone with applied experience, and 2) the very process of Bayesian inference that relies on the – apparently subjective – assessment of priors and posteriors generates suspicion on those with applied research expertise (Gelman A. Objections to Bayesian statistics. *Bayesian Analysis*, 2008, 3:445–50.)

¹⁷ The number needed to treat (NNT), the number of patients who need to be treated in order to prevent one additional bad outcome (i.e. to reduce the expected number of cases of a defined endpoint by one), is computed simply as the inverse of the absolute risk. It serves primarily in assessing the effectiveness vs. risk of a health-care intervention, often but not always a treatment with medication. The converse of NNT is the number need to harm (NNH), which pertains to the domain of undesirable side-effects (Chiappelli et al, 2002c; Chiappelli, 2008).

performance of evidence-based dental care, it lacks statistical stringency. Independent data analysis produces inferences rarely based on statistical significance, but that can have profound clinical relevance.

What is all the more troubling, at this stage of the growth, evolution and establishment of the field of evidence-based decision-making in dental care is that the purpose, methods and procedure of the evidence-based process seeks and wants the highest statistical stringency: therefore, as stated, it involves elaborate acceptable sampling analyses and meta-analyses to generate a consensus of the best available evidence. But in so doing, it finds little room for individual data analysis – because it does not yet have the capability to do so.

Arduous conceptual and analytical work must be developed in a timely fashion to establish and characterize the manner in which the analysis of individual independent patient data came become integral part of the systematic review process. This is a *sine qua non* for the viability of the field.

It is also the case that, in dentistry and in medicine, and actually in the health sciences in a broader scope¹⁸, the evidence-based process may take one of three perspectives:

- a) We can evaluate a body of evidence based on "what" was done (cf., note 15), and in this manner rank and obtain a semi-quantification of the "level of the evidence". We might say, for instance, that systematic reviews and meta-analyses must obtain a "level of evidence I", and that randomized controlled trials ought to rated "level of evidence II" (Figure 3). Observational studies might thus be ranked lower, regardless of the fact that in certain domains of clinical dentistry it is often impossible to design a traditional randomized and well-controlled trial. Consequently, for certain domains of dentistry, where these supposed "optimal" studies cannot be performed, the "level of the evidence" is bound to be lower than (some vaguely accepted) standard (Sackett et al, 1996; Friedland et al, 1998).

**Meta-Analysis
& Systematic Review
RCT's
Cohort Studies
Cross-Sectional Studies
Case & Case Control Studies
Case Reports Animal & Laboratory Studies**

Figure 3. Level of Evidence.

¹⁸ As a note added in proof of concept, it is interesting to observe how generalized the process of evidence-based decision making has become over the past decade, well beyond the health sciences alone – from economics, to correction law, to political sciences, and so on.

- b) We evaluate "how" it was done (cf., note 15), "why" it was done, and "what might be the clinical outcomes" (utility, patient satisfaction, etc.). We can utilize stringent criteria issues of research methodology, research design, and data analysis to quantify this evaluation protocol, such that the literature that is examined by means of this stringent critical appraisal can be subjected to a process of disqualification of the evidence that is not acceptable (Egger et al, 2001; Moher et al, 2001; Cluzeau et al, 2003; Chiappelli, 2008). The evidence that survives this "acceptable analysis" is evaluated for an overarching analysis of the data across the published reports, and, if adjudicated as "homogeneous", then incorporated in the stringent meta-analytical protocol.
- c) In the best of circumstances, we evaluate both *what* (i.e., level of evidence) was done and *how* it was done (i.e., acceptable quality, meta-analysis), and thus generate a superlative systematic review of the best available evidence (Figure 4).

In brief, dental care is a clinical endeavor. As such, it deals with each patient needs and wants individually. The clinical relevance of a group-driven process of statistical data amalgamation and analysis to the domain of the "patient-oriented evidence that matters" (Glick, 2007) is not immediately clear. Not to say that it is non-applicable – if it were, then what would be the purpose of doing oral biology research at all? – but, it is in urgent need of careful consideration both from the perspective of the evidence-based researchers (i.e., in terms of the statistical tools that must be devised and optimized for this purpose), and of the evidence-based clinicians, who must uncover the latitude of the field in order to be able to practice it confidently with their patients.



Figure 4. Toward Optimizing Evidence-Based Decision-Making.

c. Reviewing Systematic Reviews: Toward “Meta-Systematic Reviews”

Many traditional, medical and dental review articles often suffer from being “...haphazard and biased, often reflecting the opinion of the review’s authors...”, (Mulrow, 1987), and that this concern contributed to the rationale of elaborating the concerted criteria for systematic reviews (Mulrow, 1994; Jadad et al, 1997; Glenny et al, 2003; Papadopoulos and Gkiazouris, 2007; Chiappelli, 2008). Standards for systematic reviews have now been articulated so that they all follow (or should follow) an explicit, well-described, widely agreed on scientific protocol, methodology and analysis (cf., note 12). The purpose of systematic reviews is to reduce both systematic errors and biases in the clinical decision-making process, and to minimize random errors by assimilating several studies with similar outcome measures (i.e., “homogenous”). In so doing, one strives to provide a more objective (i.e., systematic), comprehensive view of the research evidence (i.e., “best available evidence”). One directionality of the systematic review is to assimilate the published quantifiable findings of in order to generate a master statistical analysis across them: this is permissible, so long as the studies are “homogeneous” and free of biases (e.g., publication bias), although, and clearly, other stringent assumptions apply (Glass et al, 1981; Stroop et al, 2000; Moradi et al, 2006).

As was briefly introduced above, an analysis of this type, the meta-analysis, is all the more powerful statistically because it combines the sample sizes of all the studies in the analysis. Statistical power (i.e., the strength of the probability one has to finding a significant effect, if there is one) increases as sample size increases, because random noise is washed out, and individual differences are normalized. By reverse of this very logic, one could say that the larger the sample size, the easier it might be to come to obtain statistical significance even of very small (irrelevant?) effects. That is to say, the very power of the meta-analysis may be put into question, since statistical significance ought to, really, be more of practical use to clinicians (i.e., more indicative of the efficacy of a treatment), when obtained with a smaller, rather than a larger sample size.

In brief, as evidence-based dental care increasingly rests on the consensus of the best available evidence to revise clinical practice guidelines, it is critical that the instruments and the process utilized to reach that consensus be scrutinized, evaluated and standardized. It is imperative that systematic reviews be of high quality and follow a rigorous, detailed and tested protocol, including for the meta-analytical processing of the data (Mulrow, 1994; Glenny et al, 2003; Papadopoulos and Gkiazouris, 2007; Bader and Ismail, 2008; Chiappelli, 2008).

As dental care increasingly rests on the best available evidence, when appropriate (*vide supra*), it will become increasingly apparent that numerous systematic reviews may become available within given PICO¹⁹ constraints. Some may be revisions or up-dates of previous ones. Others may be *de novo* systematic reviews. Regardless of how they will come into the scientific literature, these systematic reviews will eventually clutter the clinical panorama in exactly the same manner as Cochrane decried the mere quantity of clinical trials was cluttering the medical literature four decades ago. In brief, by producing multiple systematic

reviews, we have now created a problem similar to that which gave rise to the evidence-based movement – except at a secondary level of complexity: not at the level of the individual clinical trials, rather at the level of the systematic critical synthesis of several clinical trials. Therefore, we must now develop means to go beyond critical evaluations of individual research studies on the basis of the level of evidence or the quality of the evidence (Chiappelli and Cajulis, 2008): we must develop tools for the quantification and statistical analysis of the evaluation of the level and quality of systematic reviews, generating what might be come to be called “meta-systematic reviews”.

Early in the establishment of the field of evidence-based dentistry, Alejandro Jadad and his colleagues of the McMaster Group noted that systematic “...(R)reviews can disagree in 2 ways: their results can diverge, or the interpretations and inferences made by the review authors can be discordant....(and that)...differences among reviews are regarded as important if they lead to different health care decisions, with implications for patient outcomes, costs of treatment or both...” (Jadad et al, 1997). The authors articulated an algorithm based on the principal types of discordances that may emerge across systematic reviews tailored to address the same PIC/PO question. In brief, the following potential sources of discordance among systematic reviews were identified:

- Statement of the clinical question
- Search of the pertinent literature, extent and inclusion and exclusion criteria
- Data extraction (direction of effect, magnitude of effect, statistical analysis and inference)
- Evaluation of level and quality of the evidence
- Acceptable analysis and meta-analysis (and associated bias)
- Overall inference and interpretation into consensus statement

These salient points were more recently re-examined²⁰ and reiterated (Papadopoulos and Gkiazouris, 2007), and expanded for use in the evaluation of systematic reviews obtained from “lesser” evidence studies, such as observational studies (Stroup et al, 2008).

To what extent the meta-analytical protocol can be expanded to produce a reliable statistical analysis and inference across several homogenous meta-analyses is a challenge that only highly skilled and qualified statisticians must tackle. So long as a “meta-meta-analysis” procedure is not articulated by statisticians, tested and verified for statistical stringency, the field will be devoid of reliable means to reach consensus on the combinatorial probabilities of the observed best available outcomes.

Be that as it may, evidence-based dental care will progress to this next level of complexity – or, better stated, has progressed, whether we have noticed it yet or not, to this second level of complexity where several, often disparate systematic reviews are available on

¹⁹ Acronym, as discussed above, for Patient population under interest, Interventions under scrutiny, Comparison across these interventions, clinical Outcome sought

²⁰ Ismail & Bader (2004) thusly summarized the issue at present: “...The current emphasis needs to shift toward expanding the topics for which systematic reviews are prepared, strengthening the quality of the systematic reviews where necessary, initiating well-designed clinical studies in areas identified as lacking or having minimal evidence, and ensuring that the information from these activities is provided to practicing dentists to benefit the oral health of the general public ...”

the same topic. It is timely and critical to come together with fundamental principles that will permit the systematic evaluation of individual systematic reviews in order to reject the inadequate ones and keep and pull together the better ones. This will be a process of acceptable sampling akin to what is done presently in the generation of the systematic review, when the level of the quality of the evidence is assessed: the product of that assessment is the elimination of sub-standard research studies, deemed so because they fail to meet the basic and commonly agreed to standards of research methodology, designs and statistical analysis (Chiappelli, 2008). This process is obtained by means of reliable and validated instruments, which permit to quantify the individual domains of methodology, designs and analysis.

In brief, in order to generate acceptable sampling analysis of systematic reviews in the process of performing a meta-systematic review, similar instruments will have to be developed, and tested for reliability and validity. They will have to produce quantifiable assessments of those fundamental principles, which over the course of the last decade, we have learned to accept as key to sound systematic reviews and meta-analyses (Mulrow, 1994; Jadad et al, 1997; Glenny et al, 2003; Bader and Ismail, 2004; Papadopoulos and Gkiazouris, 2007; Moradi et al, 2006; Chiappelli, 2008; Stroup et al, 2008). A succinct preliminary list of these principles are reiterated below:

1. PICO question quality (e.g., appropriately focused PICO question)
2. Search quality (e.g., appropriately representative papers, appropriate search, appropriate inclusion/exclusion criteria, language and other biases)
3. Evidence assessment (e.g., level of evidence, quality of the evidence)
4. Analysis (e.g., none, acceptable sampling, meta-analysis, bias analysis)
5. Inference and process of consensus (e.g., forced consensus, proposed revised clinical practice guidelines)

Based on these generally accepted criteria of the necessary components of a good-to-satisfactory systematic review, we are in the process of developing and validating an instrument for quantifying the quality of the evidence presented in a systematic review to optimize the evidence-based decision-making (Chiappelli et al, in preparation).

III. Conclusion: The Value-Utility Model in Evidence-Based Dental Care

In brief, evidence-based decision-making in health care practice rests on seven fundamental contingencies (Reeves et al, 2006; Chiappelli and Cajulis, 2008; Machikanti, 2008):

- recognition of the patient's problem
- construction of a structured clinical question
- thorough search of medical literature
- evaluation of the evidence for quality and level of evidence
- retrieval of the best available evidence to answer the question

- critical appraisal of all available evidence into revised clinical guidelines
- integration with all aspects and contexts of clinical decision-making

Systematic reviews provide a tool to apply stringent scientific strategies to quantify the quality of the accumulated research evidence in order to limit bias during the application of this evidence to the resolution of clinical problems. Systematic reviews utilize and integrate both acceptable analysis and meta-analysis to establish the level of overall significance of the gathered evidence, and are therefore vastly different from narrative reviews and health technology assessments (Chiappelli and Cajulis, 2008; Machikanti, 2008).

Clinical practice guidelines are systematically developed statements that aim to provide health care providers (i.e., in the present context, dental care providers), insurance coverage providers, and the patients with the best available updated information to optimize health care decisions. The guidelines must incorporate validity, reliability, reproducibility, clinical applicability and flexibility, clarity, development through a multidisciplinary process, scheduled reviews, and documentation. Evidence-based clinical dental practice guidelines therefore represent statements developed to improve the quality of dental care, patient access, treatment outcomes, appropriateness of care, efficiency and effectiveness and achieve cost containment by improving the cost benefit ratio (Bauer et al, 2006; Machikanti, 2008).

Be that as it may, it remains that dentists provide dental care to individual patients, one at the time. Dentists at the cutting-edge of their profession will follow the recommendations of their professional association, and adopt an evidence-based practice, rather than continue the now out-moded model of practice merely based on this or that piece of evidence. In order to actualize their intent of practicing evidence-based decision-making in the process of designing treatment plans specific to the dental care needs of each patient, they must rely on systematic and meta-systematic reviews. But, they also must rely on their expert assessment of the patient's need. That is to say, evidence-based dental care is obtained when dentistry is provided in the patient-dentist-evidence triad (Bauer et al, 2006; Merijohn, 2006).

Dental care as practiced today and the prepayment systems of dentistry are substantially different than they were fifty years ago when dental insurance as we know it was first developed. Dentistry has always changed with the development of our science and the expression of dentistry's diseases in the populations we serve. The changes that are likely to occur in the future will be focused on improving health outcomes across risk-analyzed populations with the goals of providing optimal health outcomes at reasonable costs (Bauer and Spackman, 2003; Anderson, 2005).

In the context of providing dental care, an *effective* clinical decision is one based both on best available, scientifically valid evidence and dentist expertise and experience, as discussed above; but it may differ from an *efficacious* clinical decision: that is, one based on the values and preferences (utilities) of dentist and patients alike. A clinical decision can be both effective and efficacious when it involves various decision makers at different levels and with specific expertise, such that a system of oral health care, in the long term, is continually advanced with best evidence and technology, studied to produce "best practice" benchmarks, and meets the needs of the people who seek dental services (Bauer et al, 2006; Chiappelli, 2008). Arbitrating the decision process in an evidence-based paradigm is to consider all relevant influences that may impact on the management and use of knowledge in making

evidence-based decisions. Best practice models suggest that public and private forces influence dental decision-making by directly influencing benefit structures, reimbursement, and indirectly the implementation of a state-of-the-art dental practice (Beutler, 2005).

Evidence is knowledge. And knowledge is a commodity that has three basic components, which are used to obtain evidence-based decisions in the health care, the political, the economic, the social, or any other societal realm with agenda-based purposes, such as equity, spending accountability, and reduction in variability (Bauer et al, 2006):

In the context of dental care, the best available evidence thus becomes a health service tool used to measure the number of people served and the cost of their services, which in turn can provide support for political decisions to include or exclude certain dental benefits in social programs based, to justify their coverage costs against competing priorities. Allocation of public monies for these benefits must be accountable to the public. The best available evidence can be used (*nota bene*., and abused) to justify, justly or unjustly, spending based on actual or politically perceived rights. Evidence-based decision-making is a useful, albeit potentially dangerous, societal and political tool to manipulate socio-economic policies aimed at diverting funding and support for necessary coverage for dental care. These interventions aim to benefit certain groups of citizens, but may also serve to the detriment of others²¹ (Bauer et al, 2006).

In the public sector dominated by insurance coverage, evidence-based decision-making is largely sensitive to costs and numbers. Insurance companies and actuaries use the best available evidence to compute and evaluate benefit structures that optimize costs yet attract purchasers of dental care products (e.g., care plans). In the private sector, ruled primarily by the wealth of the individual patient, evidence-based decision-making is driven understandably so more by commodity and patient wants, than by the societal economics insurance coverage (Donaldson et al, 2002). In both instances, patients often want to be empowered to be part of a shared decision-making process, where patient-centered and dentist-centered improve and validate the process of reaching a treatment plan consensus during the consultation. Clearly, shared evidence-based decision-making tends to increase patient motivation and compliance, and to decrease the possibility of litigation (Bauer et al, 2006). Clinical decisions can follow:

- the *intuitive approach* applies to those situations in which the presenting condition and patient characteristics are consistent with findings that are associated with predictable outcomes. The dentist's expertise helps to recognize these types of clinical situations triggered by key elements that are rapidly integrated into a mental model of diagnostic categories and an overall concept of treatment modalities. Treatment options derive directly clinical experience and judgment to meet accepted standards of care.
- the *analytic approach* applies specifically to those presenting conditions and patient characteristics that are less certain, and that require recommending treatment modalities whose benefits and harms are variable or unknown. Here, clinical

²¹ well then, the argument cited above that the evidence-based process is a "conspiracy" of some sort may not be completely untenable, when viewed under this light.

experience and judgment is insufficient in meeting accepted standards of care, and clinical decisions must be carefully pondered. Decision aids, such as the Markov tree discussed above, are sought. The evidence-based decision-making paradigm states that it is these particular cases of dental care that must rely on the best available evidence.

Shared decision-making may not be needed for all clinical situations. The process of analytical clinical decision-making often rests on a decision process, a type of algorithm that presents a visual representation of instructions to approach the decision process, based on inclusion/exclusion symptoms and signs, which act as specific nodes in the graphical representation. Decision nodes are linked and organized into clinical pathways of intervention, which are congruent with the recommended clinical practice guidelines. In the current vein of evidence-based dental care, clinical decision trees must include the best available evidence and evidence-based revisions of clinical practice guidelines (O'Connor, 2007). *De facto*, decision trees compare probabilities assigned to branches leading from each choice node, depending on the type of evidence (e.g., relative risk, patient functioning, patient satisfaction). Utility data may consist of objective probabilities, such as numeric values, and subjective probabilities, which are developed from adjustments for which a value is assigned, and may characterize the patient's include age, education, beliefs, and attitudes, preference for choosing one treatment over another, etc. (Minelli et al, 2004). Presenting utility data in the decision tree may benefit from categorizing utilities by patient's risk-taking behaviors. The categories include those patient who are more cautious, or risk adverse, those who are more freethinking, or risk tolerant, and those who are equipoised, or risk neutral (Lilford, 2003). Whereas utility data indicate what choice is most important when considering a patient's values and preferences, economic data is the result of integrating the costs of treatments into the decision tree. Costs may vary from region to region. In decision trees, costs measures ought to reflect local or individual practice scales. The result of economic data points to which choice is less expensive.

Decision analysis combines the best available evidence to the utility and economic data. A maximized decision reconciles best evidence of treatments or therapies with conditions and circumstances of individual patients. The decision tree can assist the dentist and patient in shared decision-making, particularly when the evidence is mixed, or the case complex. But, one disadvantage of decision trees is that they may be too prescriptive, or arduous when instructions and included guidelines are overly numerous (Bauer et al, 2006; Chiappelli, 2008).

In conclusion, it must be noted that It has been proposed that a XXI Century view of translational evidence-based decision-making in medical and dental care ought to provide feasible, practical as well as sustainable solutions. Clinical questions that arise from individual patients must find answers that arise from a research continuum going from the patients needs and wants and the clinician's knowledge, abilities and expertise, to a comprehensive systematic evaluative analysis and critical synthesis of the research literature²², to the generation of fundamental queries to be answered by fundamental and

²² as discussed elsewhere (cf., Chiappelli, 2008), critical appraisal of the literature is obtained by means of standardized instruments such as the MOOSE and the Wong scales for observational studies, the Wong scale for experimental research, and the CONSORT, Jadad and Wong scales, for example, for the evaluation of

clinical trials. QUOROM is an instrument designed to evaluate the quality of meta-analyses. As discussed above, current work by our group and others are targeted at characterizing the reliability and validity of novel instruments designed to compare and contrast discordant systematic reviews.



Figure 5. Toward Sustainable Evidence-Based Decision-Making.

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Chapter 5

Traumatic Dental Injuries: Preventive and Public Health Approaches

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Abstract

Dental trauma can involve injuries to hard tissues and pulp, to periodontal tissues, to bone tissue, and to gingiva and oral mucosa. The aetiology of dental injuries is multifactorial as they are caused by a complex array of individual clinical factors and social/environmental determinants. Traumatic dental injuries are mainly sustained during sports, through accidents and as a direct result of violence. The prevalence of traumatic dental injuries is not high but there is evidence that the incidence in children's teeth is increasing.

Primary prevention of traumatic dental injuries addresses the control of preventable risk factors through the early treatment of large overjet, the provision of safe playground surfaces and mouth protection in sports. Secondary prevention includes prompt, accurate diagnosis and appropriate initial management in order to improve the prognosis of traumatic dental injuries.

Available evidence indicates that traumatic dental injury is a significant public health problem. Therefore, a treatment approach is unlikely to be successful unless a complementary public health strategy is adopted. Effective public health action should provide high quality clinical care with staff specialized in traumatic dental injuries treatment. Healthy public policies should provide a legislative framework for environmental change in playground layout and for the promotion of mouthguard use in high-risk sports. Health education should be expanded in schools and sport organizations in order to promote the use of mouthguards and improve first-aid treatment by lay people.

Introduction

Dental trauma can involve injuries to hard tissues and pulp, to periodontal tissues, to bone tissue, and to gingiva and oral mucosa. The aetiology of dental injuries is multi-factorial as they are caused by a complex array of individual clinical factors and social/environmental determinants. The major causes of traumatic dental injuries (TDIs) include injuries sustained during sports, accidents and injuries as a direct result of violence [1-3]. The occurrence of TDIs is related to a number of risk factors such as age, sex, malocclusion and anatomic feature, epilepsy and intubation during anaesthesia [2-4]. Dental trauma does not occur very frequently but epidemiological evidence suggests that the incidence in children's teeth is increasing [2, 3, 5, 6].

As the aetiology of dental injuries is multi-factorial, it is difficult to institute effective preventive measures. The prevention of trauma can be either primary or secondary. Primary prevention involves controlling preventable risk factors by providing early treatment of large overjet and adequate sport equipment and environment [4, 7]. The goal of secondary prevention is prompt, accurate diagnosis and appropriate initial management in order to improve the prognosis of TDIs [8, 9].

The traditional approaches to treatment and prevention (orthodontics, restoring traumatized teeth, provision of mouthguard in contact sports) have only a limited effect on the problem of TDIs, due to the multi-factorial aetiology, and the complexity and long-term nature of treatments. Available evidence also indicates that TDIs constitute a significant public health problem [5, 6, 10]. Therefore, a clinical approach is unlikely to be successful unless a complementary public health strategy is adopted. Effective public health action should provide high quality clinical care by staff who offer trauma service regularly, and so who have a high professional skill and experience to successfully treat cases that are presented to them. Healthy public policies should also provide a legislative framework for environmental change in playground layout, for the promotion of mouthguard use in high-risk sports and for the supervision of young people's play. Moreover, education programmes should be implemented in schools and sport organizations in order to achieve improvements in first-aid treatment by lay people and to expand the use of mouthguards.

Aetiology and Risk Factors

Dental injuries can either be the result of direct or indirect trauma. Direct trauma occurs when the tooth itself is traumatized while indirect trauma occurs when the lower dental arch is forcefully impacted against the maxillary teeth.

The aetiology of TDIs is multi-factorial as they are caused by a complex array of clinical factors as well as social/environmental determinants. Individuals who have incisal and maxillary protrusion, increased overjet (>6 mm) and inadequate lip coverage have an

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increased risk and their injuries also tend to be more severe [11, 12]. It was also observed that the severity of injuries appeared to increase when there is an associated injury to the lower lip, while a third of the accidents occurred in subjects with some form of malocclusion [4].

The social, economic and environmental determinants are also recognized as being fundamentally important. Accidents caused by falls, contact sports, traffic and bicycle accidents, accidents in and around the home appear to be common causes of dental injuries [1-3, 11, 12]. The Fédération Dentaire Internationale (FDI) has recently classified organized sports into two categories: 1. high-risk sports (American football, hockey, ice hockey, lacrosse, martial sports, rugby, football, skating), 2. medium-risk sports (basketball, diving, squash, gymnastics, parachuting, and water polo) [13].

Other possible social/environmental causes include violence, deprivation/overcrowding, falls, and poor environments. Although a strong social class gradient exists for childhood deaths caused by injury, the link between dental trauma and deprivation has not been thoroughly investigated. However, the surveys from deprived areas in the north-west of England and the east end of London have shown far higher rates of TDI than the national figures [14, 15]. Moreover, the study in London identified a greater risk of TDI for subjects living in overcrowded households [15]. A recent Canadian survey did not find the relationship between dental injuries and the socio-economic status [3]. However, a statistically significant direct relationship was shown between increased caries experience and TDI. This should focus attention on possible common-risk factors such as health-related behavioural problems that may affect both dental disease and TDI. Some traumatic injuries can also be attributed to violence, particularly in later adolescence, or abuse, especially on children [16]. Yet dental damage may be caused by excessive force applied to the teeth during laryngoscopy, especially in younger patients where the anterior teeth are only partially erupted and root length is not complete [17, 18]. Another less frequent risk factor is epilepsy.

Classification

There are numerous classification systems currently available for TDI (Table 1).

Andreasen's classification is a modification of the World Health Organization's (WHO) and contains 19 groups that include injuries to the teeth, supporting structures, gingiva and oral mucosa. Unlike the WHO classification, the socket and fractures of the mandible or maxilla are not grouped under oral injuries, but rather are classified separately as fractures of face bones. It is a very comprehensive system which allows for minimal subjective interpretations [19].

The WHO classification of oral trauma describes injuries to the internal structures of the mouth and incorporates of a broad group "other injuries including laceration of oral soft tissues" [20].

García-Godoy's classification is also a modification of the WHO system. This classification differs from others mainly because it separates dental fractures into those which involve cementum and those which do not. Moreover, there are no groupings for subluxation or alveolar injuries and mandible or maxilla fractures [21].

Table 1. Classifications of traumatic dental injuries

Andreasen [19]	World Health Organization [20]	García-Godoy [21]	Ellis [22]
Crown infraction. Incomplete fracture of the enamel	Fracture of enamel of tooth	Enamel crack	Crown fracture involving enamel
Uncomplicated crown fracture. A fracture confined to the enamel or dentin but not exposing the pulp	Fracture of crown without pulpal involvement	Enamel fracture	Crown fracture involving enamel and dentin
Complicated crown fracture. A fracture involving enamel and dentin, and exposing the pulp.	Fracture of crown with pulpal involvement	Enamel-dentin fracture without pulp exposure	Crown fracture with an exposure of the pulp
Uncomplicated crown-root fracture. A fracture involving enamel, dentine, cementum, not exposing the pulp	Fracture of root of tooth	Enamel-dentin fracture with pulp exposure	Loos of the entire crown
Complicated crown-root fracture. A fracture involving enamel, dentin and cementum, and exposing the pulp	Fracture of crown and root of tooth	Enamel-dentin-cementum fracture without pulp exposure	Total tooth loss
Root fracture. A fracture involving dentin, cementum, and the pulp	Fracture of tooth, unspecified	Enamel-dentin-cementum fracture with pulp exposure	Fracture of the root, with or without loss of crown structure
Concussion. Injury without abnormal loosening or displacement but with marked reaction to percussion	Luxation of tooth	Root fracture	Displacement of tooth, without fracture of crown or root
Subluxation (loosening). Injury with abnormal loosening but without displacement of the tooth	Intrusion or extrusion of tooth	Concussion	
Intrusive luxation (central dislocation)	Avulsion of tooth	Luxation	
Extrusive luxation (peripheral dislocation, partial avulsion)		Lateral displacement	
Lateral luxation		Intrusion	
Exarticulation (complete luxation)		Extrusion	
		Avulsion	

The Ellis classification is another modification of the WHO system. This system is a simplified classification which groups many injuries and allows for subjective interpretation by including broad terms such as “simple” or “extensive” fractures. Injuries to the alveolar socket and fractures of the mandible and maxilla are not classified here [22].

Epidemiology

Data on the extent and severity of TDI is rather limited in comparison to the amount of information available in relation to dental caries and periodontal disease.

An Australian study by Stockwell [23] determined that the incidence of trauma to the anterior permanent teeth in 6-12 year old school children was 1.7 patient/100 children/year and 2.1 teeth/100 children/year. An English study by Hamilton et al. [14] determined the incidence of trauma to permanent incisors and related soft tissues as four cases/100 children/15 months, which was almost twice the incidence of the Australian study. Significantly more children from lower socio-economic groups sustained dental injuries compared with the higher socio-economic groups in the English study. This, together with the inclusion of soft tissue injuries in the English study, may provide a possible explanation for the large differences between the two studies, particularly if the socio-economic status was not evenly distributed in the two geographical locations.

Calculating the prevalence of TDI is a relatively simple task and most studies have calculated this figure [4, 14, 24, 25]. Prevalence is defined as the number of events, in this case the number of children experiencing TDI, in a given population at a designated time period. The prevalence of TDI in various epidemiological studies has also been found to differ considerably. The great variation may be due to a number of different factors, such as the trauma classification, the dentition studied, geographical and behavioural differences between study locations and countries. The prevalence of TDIs in children aged 6 was around 30%, whereas in high school children ranged from 6% in an Australian study by Burton et al, to 34% in an English study by Hamilton et al [14, 24]. A South African study by Hargreaves et al. found a prevalence of 16% in primary school children, whereas in Canadian children aged 12 and 14 the prevalence of dental injuries was 11.4% [25, 3]. An American study by Kania et al. found an overall prevalence of traumatized incisor teeth to be significantly higher among non-Caucasians compared with Caucasians, 17.5% and 21.7% respectively [4]. On the other hand, in South Africa the native population had a TDI prevalence of 13% whereas in the Caucasians a prevalence of 21% was found [25].

Unlike in caries, where a significant decrease in caries activity has been found over the past two decades, the occurrence of TDIs shows the opposite trend. In fact, in some countries, including the UK and Sweden, dental trauma prevalence on anterior teeth was greater than that of caries [5, 6, 26, 27]. Males experienced significantly more dental injuries to teeth than females in most international surveys, probably because they usually participate to more violent sports. The male:female ratio ranged from 1.3 to 2.3:1 [4, 11, 12, 14].

Dental injury incidence decreases with age, with two main “peak periods” described as being between the ages of 1 and 3 and again between the ages of 7 and 10 [3, 14, 18]. For children under 3 years old, who are usually both unsteady on their legs and lacking in a

proper sense of caution, falls are the most common cause of injury. In school-age children, bicycle, skateboard and road accidents are the most significant factors, while in adolescence there is another, although less marked, peak largely due to sports injuries. Most of these injuries result from participation in contact sports such as American football, rugby, soccer, boxing, wrestling, diving or stick sports. However, other sports like skiing, skating, cycling, and horse riding, which do not involve player contact, may also place the participant at risk [1]. In later adolescence and in adulthood, a high percentage of TDIs can be attributed to car accidents and physical violence. Moreover, accidents within and around the home have been reported as being the major source of injury to the primary dentition, while accidents at home and school accounted for most injuries to the permanent dentition [2, 11, 23].

The number, type and severity of dental injuries per patient differ according to the patient age and the cause of accident. Uncomplicated crown fracture without pulp exposure was the most common injury to the permanent dentition reported in most studies [4, 23, 28, 29]. Subluxation and complete luxation are also frequent, particularly in the primary dentition, whereas luxation of teeth usually occurs more frequently in young people [30, 31]. Supporting structures (alveolar bone and periodontal ligament) in the primary dentition are resilient, thereby favouring displacement rather than fracture. The maxillary central incisors are the most frequently injured teeth in both primary and secondary dentition [11, 12, 28-31].

The number of injuries per patient has varied from 1.1 to 2.0, but this variation could have been influenced by the actual injuries being recorded, the classification used and the study location [3]. For example, one tooth was more frequently injured than multiple teeth in most prospective studies conducted at school dental services and general clinics [23, 28, 29]. The studies conducted in hospital casualty departments and in after hours clinics reported injuries to one and two teeth in equal proportions or two teeth more frequently than one [32, 33]. This may be the result of people experiencing more severe injuries after hours and it may also indicate that people attend hospitals rather than dental clinics for more severe injuries.

Primary Preventive Measures

Playground Surfaces

The most common cause of TDI in children is falling on to a hard surface. Any organization responsible for the purchase of play equipment should ensure that an impact-absorbing surface is provided around the items from which children are most likely to fall. A fall onto an impact-absorbing surface means that a fall is cushioned and therefore the child is less likely to be seriously hurt. In addition to the consideration of the playground surface, the play equipment should not include free-standing slides, but instead be built into earth mounds. However, no matter how safe the equipment or the playground's layout, there is always a risk that children will trip or stumble, run into each other or a piece of equipment, lose their footing or lose their grip or even more seriously, fall from a height. Therefore, parental or professional supervision of children at play should be considered the most effective way of preventing serious injury.

Early Treatment of Large Overjets

The incidence of accidental damage to permanent incisors significantly increases with overjets greater than 6 mm [4]. Orthodontic treatment in early mixed dentition is classically carried out in uncrowded arches using functional appliances or extra-oral traction. Both treatments work best during active growth and in some cases may be a favourable influence on growth. Starting treatment early does not always produce an early finish, and treatments can be prolonged by extractions and use of fixed orthodontic appliances.

Mouth Protection in Sports

Many dental injuries associated with sports are preventable by the use of protective athletic equipment. Mouthguards have long been promoted as a way to reduce the incidence of traumatic oral injuries. The American Society for Testing and Materials (ASTM) has defined a mouth protector as “a resilient device or appliance placed inside the mouth to reduce mouth injuries, particularly to teeth and surrounding structures”. A mouthguard generally separates the upper and lower dentition and at least a portion of the teeth from the surrounding soft tissue. Mouthguards are thought to reduce the likelihood of oro-facial trauma through several mechanisms. Firstly, they may prevent fracture or dislocation of the teeth by separating the mandibular and maxillary teeth and absorbing or redistributing shock during direct forceful impacts. Secondly, they provide the mandible with resilient support which absorbs impacts that might fracture the unsupported angle or condyle, redistributing shock and/or stabilising the mandible during traumatic jaw closure. Thirdly, the mouthguard holds the soft tissues of the lips and cheeks away from the teeth, thus preventing laceration or bruising of the lips and cheeks against the hard and irregular teeth during impact. Moreover, the mouthguard prevents opposing teeth from coming into violent contact, reducing the risk of tooth fracture, or damage to supporting structures. Finally, it is presumed that the mouthguard may reduce the likelihood of concussion due to a direct blow to the jaw by positioning the jaw to absorb impact forces that would normally be transmitted through the base of the skull to the brain [7].

Studies that have examined injuries among mouthguard users and nonusers consistently showed that mouthguards offer significant protection against oro-facial injuries during sports [34, 35]. Meta-analysis indicated that the overall risk of an oro-facial injury is 1.6-1.9 times higher when a mouthguard is not worn [7]. At present, mouthguards are recommended in some sports (football, ice-hockey, men’s lacrosse, women’s field hockey) to reduce both the likelihood and severity of TDIs. The only professional sport that requires a mouthguard to be worn is boxing, but increasing numbers of professional athletes in other sports seem to be voluntarily using mouthguard [7]. A study investigating mouthguard use in elite female field hockey players reported that 88% of the players said that they owned a mouthguard, but only 50% of the subjects said they wore it all the time during training, even though the international hockey organizations recommend that players wear mouthguards when playing [36].

Mouthguard Construction and Design

The criteria for constructing an effective mouthguard and the characteristics of a properly fitted mouthguard have been defined by the FDI [13]. A mouthguard should be made of a resilient material that meets Food and Drug Administration approval and which can be easily washed, cleaned and readily disinfected. The most common used material is polyvinyl acetate-polyethylene copolymer (PVAc-PE). Mouthguards should have adequate retention to remain in position during sporting activity, and allow for a normal occlusal relationship to give maximum protection. They should absorb and dispense the energy of a shock by covering the maxillary dental arch, excluding interferences, reproducing the occlusal relationship, allowing mouth breathing, and protecting the soft tissues. Mouthguards should cover all remaining teeth in the maxillary arch except in athletes with mandibular prognathism. In these instances, all teeth in the mandibular arch should be covered instead. Adolescent athletes wearing fixed orthodontic appliances can have a mouthguard providing that the brackets and arch wires are covered with wax prior to taking an impression. Partially dentate athletes should not wear removable prostheses while participating in sports in order to prevent injury or aspiration of fragments if the appliance were to fracture. Occlusal rims may be constructed on a thermoplastic base to replace the missing teeth. According to FDI recommendation, mouthguard should be manufactured by the dentist from an impression of the athlete's teeth [13].

Types of Mouthguards

Mouthguards can be classified into three types: stock, mouth-formed, and custom-made.

Type I stock mouthguards are popular because they are inexpensive and are readily available in most sporting stores. They can only be kept in place by biting the teeth together. However, because they are preformed and are worn directly as manufactured, they are the least retentive, the most bulky, and interfere most with breathing and speech.

Type II mouth-formed guards are available in two types: shell lined and boil and bite. The first is made with a firm shell in the form of dental arch, which is filled with a resin that is adapted to the teeth. The resin sets in the mouth after 3-5 minutes and remains resilient at mouth temperature. Unfortunately, this appliance is extremely bulky and it makes normal speech virtually impossible. The margins of the outer shell may also be sharp unless protected by an adequate thickness of the lining material. The second most commonly used type of mouth-formed guard is constructed from a preformed thermoplastic shell that is softened in warm water and then modelled in the mouth by the athlete using tongue and fingers. Even under professional supervision it is difficult to mould this type effectively. The temperature necessary to allow adequate adaptation for the teeth is fairly high and there is a risk of burning the mouth. In addition, they are too bulky at the periphery or too thin over the critical occlusal table, and are often uncomfortable.

Type III custom-fabricated mouthguards are far superior to the other types in terms of adaptation, retention and protection. They are the most comfortable and interfere the least with breathing and speech. They are fabricated over a dental model using sheets of thermoplastic material. Because this technique requires the services of a dentist, the final product is more expensive for the customer than the other types of mouthguards [7].

Mouth Protection in Laryngoscopy

In anaesthetic practice, the use of mouthguards may reduce tooth injury. Two types of devices have been developed: the individually adaptable ones, using thermoplastic material, and the preformed ones. Preformed dental shields were shown to be useful in reducing the force applied to the teeth and can potentially reduce the probability of tooth damage during intubation anesthesia [37]. Further studies are needed to evaluate which model of tooth protector is most effective at reducing the risk of TDI during laryngoscopy.

Secondary Prevention and First-Aid Service

Prompt intervention following accidental damage to teeth can have a secondary preventive effect by reducing the complications of trauma. The immediate demand of a dental trauma appears to be diagnosis of the involved oral tissues (pulp, periodontium, alveolar bone, gingiva or mucosa). This phase implies a clinical examination and usually also a radiographic examination of the traumatized region. Based on this, a diagnosis of the traumatized tissues can be made and the immediate or later treatment required can be ascertained.

Primary Teeth

Teeth which have suffered concussion injuries are sensitive to percussion without any additional sign.

Subluxated teeth also present increased mobility and widening of the periodontal space. The general therapeutic principle appears to be conservative, accepting the primary tooth in its displaced position and waiting for spontaneous realignment of the tooth. No treatment is needed, but only observation [38].

Intruded teeth may disappear completely into the surrounding tissues or the incisal part may remain visible with its clinical crown shorter than an adjacent non-traumatized tooth. Percussion of an intruded tooth produces a metallic sound and does not provoke pain. If the root of the primary tooth is pushed against the crown of the permanent tooth, it may severely damage the developing tooth bud. Immediate removal of the primary tooth may relieve the pressure and minimize the damage. Intruded teeth that do not pose a threat to permanent teeth can be left to spontaneously re-erupt [38].

Extruded teeth are clinically elongated in comparison with adjacent unaffected teeth. The tooth presents increased mobility and sensitivity to percussion. Radiographically, it presents a widening of the periodontal ligament especially around the apex. The management of extrusive luxation of primary teeth includes extraction of the severely luxated tooth owing to the potential damage to the succeeding permanent tooth. For minor extrusion (<3 mm) in an immature developing tooth, either careful repositioning or leaving the tooth for spontaneous alignment are both acceptable treatment options [38].

It is recommended that avulsed primary teeth not be replanted owing to damage that may be inflicted to the permanent tooth, during insertion of the root back into its socket [38].

The injuries to the hard dental tissues without pulp exposure should be restored if larger, or sharp edges at the fracture line can be smoothed with abrasive disks to prevent irritation to the lips and tongue. Several treatment options are available for crown fracture with pulp exposure in primary teeth, including pulp capping, and partial pulpotomy. When the fracture involves enamel, dentin and root structure, tooth extraction is recommended. Root fractured teeth, if the fracture is localized in the mid-root or in the apical third, should be treated extracting only the coronal fragment. The apical fragment should left to be resorbed [38].

Permanent Teeth

In the permanent dentition, immediate treatment of a crown fracture involving only enamel is not necessary. Immediate management includes the smoothing of rough enamel edges and the placement of resin composite without extensive finishing and polishing, or indeed no treatment at all. The vibration and heat produced during finishing and polishing can further traumatize the tooth; and so it is recommended to wait 4 to 8 weeks until final polishing of the restoration is completed [8].

Fractures involving both enamel and dentin are frequently related to sensitivity. These fractures should have the dentin protected as early as possible after the trauma occurs. A periapical radiograph should be obtained to verify the extent of the traumatic incident and to provide a baseline view for subsequent comparison. Current recommendations stress the importance of sealing the dentin [39]. Consequently, the appropriate treatment is the placement of a dentin bonding agent or glass-ionomer cement over the exposed dentin, followed by the placement of a resin composite restoration. Replacement of the original fractured tooth fragment using the acid-etch technique has been shown to be successful. This technique is particularly effective for large fractures [8, 39].

In crown fractures with pulp exposure, pulp capping or a pulpotomy can be performed with a high predictability of success [39]. Pulp cap is recommended if the patient is seen within the first several days of the traumatic injury, the first few hours being ideal. The cap is usually made with calcium hydroxide and Mineral Trioxide Aggregate, an endodontic cement that is extremely biocompatible. Recently, some authors have encouraged the use of methacrylate dentin bonding adhesives for direct pulp cap agents [40, 41]. If too much time elapses between accident and treatment and the pulp becomes necrotic, root canal treatment is mandatory, whereas in extensive crown fractures it must be decided whether treatment other than extraction is feasible [39].

In crown root fractures the diagnosis is usually made clinically (tooth mobility, displacement of the coronal fragment, and pulp sensitivity) and radiographically. Treatment recommendations are the same as for complicated crown fractures. Optimal results are obtained if the coronal fragment is positioned as soon as possible [39].

In root fractures, repositioning the coronal segment of the tooth as soon as possible is recommended. The recommendations for splinting root-fractured teeth for several months have been brought into question by recent findings. Root-fractured teeth may heal better if

splinted for only 3 to 4 weeks with a functional flexible splint that allows for some mobility of the teeth. If the root fracture is near the cervical area of the tooth, stabilization is beneficial for a longer period of time. It is advisable to monitor healing for at least 1 year to determine pulpal status. If pulp necrosis develops, root canal treatment of the coronal tooth segment to the fracture line is mandatory [39].

First-aid treatment of lateral luxated and extruded permanent teeth is repositioning and splinting the teeth with a flexible splint for a variable period (2 weeks for extrusion and 4 weeks for lateral luxation). The subluxated tooth is tender when touched or tapped and has increased mobility. A flexible splint to stabilize the tooth for patient comfort can be used for up to 2 weeks. No treatment is needed for teeth involved in concussion. They should only be taken out of occlusion if the child complains of pain [39].

The treatment of choice for intrusive luxation of teeth with incomplete root formation is to reposition orthodontically using light forces, if no movement is noted within 3 weeks. Immediate surgical or orthodontic repositioning is recommended for intruded permanent teeth with complete root formation only [39]. Orthodontic repositioning appeared to lead to a slight reduction in the risk of defects in marginal periodontal bone healing [42]. Some authors do not recommend immediate repositioning in patients with complete root formation and an age of 12-17. These patients, however, must be monitored very carefully [42].

The prognosis for long-term retention of an avulsed permanent tooth worsens the longer that the tooth is out of its socket [43]. Periodontal ligament and cementum layer may in fact not heal properly when damage affects over 20% of the root surface [9]. Therefore the primary therapeutic concern is to maintain the vitality of periodontal ligament and cementum layer. It is thus imperative that the avulsed tooth be immediately replanted by the first capable person whenever possible. He/she should pick the tooth up by the crown and avoid touching the root. If the tooth is dirty, it is recommended to wash it briefly (10 seconds) under cold running water and to reposition it, encouraging the patient to bite on a handkerchief to hold it in position. If it is not possible to reposition the avulsed tooth, it has to be kept in a suitable storage medium [43, 44]. The best transport medium for avulsed teeth is cell culture media, and milk is the best alternative. While some studies have indicated that storing the tooth in the patient's mouth may be favourable toward periodontal ligament survival, the danger exists of an alarmed child swallowing, aspirating, or chewing on the tooth [45-48]. As an alternative, saline can be used, but it provides a preservation time of only 2 hours [9].

The avulsed tooth should be removed from the storage liquid avoiding contact with the root, in order not to further damage the periodontal ligament and cementum. An antibiotic solution should be applied on the root surface before tooth replantation. The blood clot is removed from the socket with saline or chlorhexidine and the tooth is replanted with slight digital pressure and fixed for 4 weeks using a flexible splint [43]. The fixation by splinting stabilizes the dental segment allowing pulp and periodontal healing [9].

Public Health Implications

A health problem can be considered as a public one depending on the prevalence of the condition, the impact of the condition on an individual level, the impact on wider society and preventive and effective treatments available [49].

Epidemiological evidence suggests that TDI constitutes a significant public health problem. In fact, although there is not a high number of people experiencing dental trauma in the majority of countries, the prevalence of these injuries has risen during the past few decades [23, 24]. The impact of condition on the individual affected varies greatly because of the variation in severity of injuries. However, the costs for the management and care of TDIs are substantial due to the complexity and long-term nature of treatments. Research from Scandinavia in the 1990s estimated a cost of US\$ 3.2-3.5 million per million subjects [50]. At a national level, in the UK the costs would therefore be very significant: about US\$ 179-196 million, calculated at 1990s prices. Moreover, although the majority of dental trauma is not preventable, with the exception of the sport-related ones, immediate intervention reduces the complications of trauma and therefore positively influences the prognosis of the traumatized teeth.

The clinical approach to the treatment and prevention of TDIs is limited, and provides a good example of the short-comings of clinical dentistry when no complementary public health approach is adopted. The clinical approach to traumatic dental injuries is limited by a number of barriers, many of which are strongly perceived by dentists. Most dentists often commence the initial treatment, but will still refer the patients to a dental trauma clinic if subsequent problems occur because of a perceived barrier. It was also demonstrated that dentists in the primary care sector had insufficient knowledge and minimal experience in treating traumatized teeth [50]. As the initial management of oro-facial may affect the prognosis for many dental injuries, it is important that the initial management of trauma is well handled. It was reported that approximately 40% of the patients presenting at the trauma clinic were referred after difficulties were encountered following initial management by the dentist, and approximately 50% of patients had received unsatisfactory or inappropriate treatment prior to referral. This seems to reflect the lack of knowledge or experience in the management of TDIs by the dentist [50]. Other barriers to caring for patients with TDIs are inadequate payment, time constraints and cooperation when dealing with children. It was reported that 72% of Australian dentists believe the treatment of TDI occupied too much clinic time, and the fees are too low for long-term monitoring [50]. The inequitable access to treatment and care should also be considered a limitation of the clinical approach in managing dental trauma cases.

Due to these barriers, the conventional clinical approach is unlikely to be successful unless a complementary public health strategy is adopted. Based upon the Ottawa Charter (WHO 1986), Table 2 outlines a range of options for a public health approach to traumatic dental injuries.

Effective public health action should provide high quality clinical care by staff who offer trauma services regularly, thus having a high professional skill and experience to successfully treat cases with which they are presented. As many injuries appear outside office hours, it is important that a dental emergency service is set up covering a given region. Such a service

should be available on a 24-hours basis. Ideally, the same dental staff should be available to provide both emergency and definitive treatment. This implies valuable constant feedback about the relationship between the extent of the initial injury, the effect of emergency treatment and the final outcome. In most cases, however, such a set-up is not possible and the referral for definitive treatment to other professionals becomes necessary. In that situation, it is necessary that sufficient information about the TDI and emergency treatment are transferred to the next treatment-provider.

Table 2. Public health approaches to traumatic dental injuries prevention

Build healthy public policy
• Promotion of mouthguard use in sports activity where there is a significant risk of orofacial injury • Recommendation to any sport organization to ensure supervision of people at play, especially for children • Fiscal policy: subsidize the costs of mouthguards
Create supportive environments
• Ensure that an impact-adsorbing playground surface is provided • Ensure that slides are built into earth mounds
Develop personal skills
• Expand personal and social education in school and sport organizations, promoting training courses for students, teachers, athletes and coaches • Expand people education of the correct first-aid treatment for traumatic dental injuries
Reorient health service
• Establish first-aid services for traumatic dental injuries within a primary care setting • Expand dentists' education and training in traumatic dental injuries treatment • Increase numbers and range of health promotion professionals within the national health services with expertise in traumatic dental injuries

Information about the immediate treatment of a trauma victim by lay people also appears to be essential. In fact, it is not the dentist but those closest to the scene of the accident which play the most important role in improving the chance of successful healing following TDI [43]. Therefore, it is necessary to carry out information campaigns aimed at educating lay people of the correct first-aid treatment. Such campaigns have successfully been conducted in several countries, e.g. Denmark, Sweden, Norway, Australia, Brazil, Argentina and the USA. Several different trauma brochures have been produced, all detailing the essential steps in emergency care. It is essential that the brochures or posters are distributed and displayed in strategic locations (e.g. sport clubs, ambulance services, schools). Similarly, information campaigns aimed at promoting the use of mouthguards in sport activities should also be carried out in school and sport settings. Finally, it is important to consider that such campaigns need to be repeated at regular intervals.

In addition, public health intervention should be focused on the reduction of the number of cases that occur by changing the underlying conditions and causes of the problem. Sport

injuries can be prevented by an athletes' training course, safe playground surfaces and the use of properly fitted mouthguards. Collaborative working across different agencies, sectors and organizations is also recommended to alter the social, economic, and environmental conditions that are linked to TDIs.

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Chapter 6

Professional Exposure to Infectious Pathogens in the Dental and Stomatological Environment

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Abstract

A review of the main infectious pathogens potentially transmissible to health care professionals during Dentistry and Odonto-Stomatological procedures is carried out, with particular attention focused on parenteral exposure in the dental, stomatological, and surgical environment. Epidemiological issues and specific risk factors are treated systematically on the ground of the available literature sources, together with all available, recommended chemoprophylactic and immunological prophylactic strategies, as updated by the updated knowledge in this field.

Keywords: Dentistry, infectious diseases, exposure, professional risk, safeguard, prophylactic measures.

Introduction

In the Dentistry-Stomatological environment, as well as in the general Surgery environment, a number of health care professional are potentially exposed to multiple, occupational infectious disease exposures. The caregivers of this specific specialty (the so-called Dental Health Care Personnel, or DHCP), include Dentists, Stomatologists, Maxillar-

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Facial Surgeons, Dental Hygiene Professionals, Nurses and operative Assistants, Laboratory Technicians, as well as Students and Residents and Fellows in the above-mentioned disciplines [1, 2].

As occurs with all other surgical and invasive procedure, the vehicles of occupational infection may be represented by blood or biological fluids containing blood, saliva, respiratory secretions, odontoiatric and surgical instrumentation, needles, lancets and other sharp instruments, as well as environmental working surfaces, air, and water supplies [2].

An elevated number of microorganisms are potentially transmissible from patients to health care personnel [2, 3]: the following organisms are of greatest importance, due to their intrinsic frequency, or the severity of the eventual occupational infection:

- hepatitis B virus (HBV);
- hepatitis C virus (HCV);
- hepatitis Delta virus (HDV) (only when chronic carriers of HBV are of concern);
- human immunodeficiency virus (HIV);
- Herpes simplex virus (HSV);
- human Cytomegalovirus (CMV);
- *Treponema pallidum*, ethiological agent of syphilis;
- *Mycobacterium tuberculosis*;
- a number of bacteria, viruses and yeasts which frequently colonized the oral cavity and upper and lower respiratory tract (i.e. Streptococci, Stafilococci, Meningococci, Influenza virus, Parainfluenza virus, Paramyxovirus, Adenovirus, Parvovirus, *Candida* spp., and many others);
- bacteria with a preferential wet habitat involving tanks, containers or wet, wet-hot surfaces, or environmental dust (i.e.. Legionellae, *Pseudomonas* spp., *Acinetobacter* spp., *Stenotrophomonas maltophilia*, atypical mycobacteria, fungi, and others) [3];
- from a theoretical point of view, the agents responsible for the Transmissible Spongiform Encephalopathies (TSE), belonging to the family of prions.

The potential routes of transmission of pathogenic microorganisms from a patient or his/her body fluids to the health care professional include:

- direct contact with blood, biological fluids contaminated with blood, saliva, or infected respiratory secretions, through percutaneous contact (i.e. accidental needlesticks or incisions or scratches), through mucosal exposure (i.e. conjunctival, oral, rhinopharyngeal), or through exposure of injured skin;
- indirect contact, descending by contacts of health care professionals with contaminated instruments or working surfaces;
- inhalation of micro-drops of saliva or respiratory secretions containing potentially infecting pathogens;
- inhalation of potentially contaminated dust, or steam;
- ingestion or mucous contact with contaminated water sources or deposits.

Like every other infectious disease pathogenesis, it remains strictly necessary that a series of conditions which allow the eventual transmission of microorganisms to the caregivers occur: among these conditions, we may mention:

- the existence of a possible source of infection (the patient undergoing cures, but also the health professional itself);
- the possibility of dissemination of the causative microorganism, from the established source of infection;
- the existence of a possible route of transmission of the eventual pathogenic microorganisms, from the established source to the host;
- the existence of a reservoir which allows the persistence and the multiplication of microorganisms (i.e. sufficient amount of blood, respiratory secretions, stagnant water);
- a microbial amount sufficient to determine human infection;
- a sufficient virulence of causative microorganisms;
- the presence of a permissive route of entry into the exposed caregiver (i.e. accidental injury, inhalation of biological fluids, interruption of physiological cutaneous barriers);
- the availability of an host (the health care professional, in our case), who remains susceptible to the relevant infection (i.e. caregivers not vaccinated, in the event of exposure to hepatitis B virus, or HBV).

Microorganisms Transmitted by Infected Blood

When looking to incidence and importance, the main occupational infections occurring in the Dentistry-Stomatological environment (similarly to those occurring in the general Surgery environment), are represented by viral hepatitis (hepatitis B and hepatitis C), and HIV infection (the agent responsible for *the acquired immunodeficiency syndrome*, or AIDS) [1-3], both transmitted by hematogenous spread.

The more common mode of potential contamination of Health Care Personnel by hematogenous-spreading infectious agents is determined by a direct contact with blood of biological fluids containing blood, via percutaneous lesions (i.e. needlestick injury, wounds or scratches caused by lancet or other sharp instruments), the exposure of non-undamaged skin, and the exposure of mucous surfaces (i.e. conjunctives, oral and nasal mucous membranes). While undamaged skin represents an affordable barrier against all infectious agents transmitted by hematogenous route, all mucous surfaces (i.e. oral, conjunctival, genital), are more permissive to hepatitis viruses B and C, and HIV infection, due to their well known anatomic and physiological features.

However, when assessing the probability of occupational infective risk, we have to take into careful consideration a broad number of epidemiological and pathogenetic variables, which may greatly modify the possibility of effective transmission of infectious agents. Among these last factors, we have to underline the following conditions:

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- the prevalence of the relevant infection in the local, general population, or in individuals who are affected by specific disorders (i.e. greater prevalence of chronic viral hepatitis among hemophiliacs, patients with end-stage kidney disease undergoing hemodialysis, i.v. drug addicts, and institutionalized patients);
 - the level of viremia in the relevant, infected patient (when viral agents with a quantifiable plasma viral load are of concern, like HCV, HBV, and HIV);
 - the type and frequency of percutaneous or mucous contact(s);
 - the amount of potentially infected material injected, or the amount of microbial organisms involved in the accident (infecting microbial load);
 - the caregiver's susceptibility state, and his/her immune defence status.

From an epidemiological point of view, during a survey conducted among 101 Dentistry specialists also practicing local anesthetic procedures in the United States and Canada, 58% of Health Care Professionals referred at least one occupational exposure to infectious agents characterized by hematogenous spread during the last six working months [4]. The contacts were predominantly percutaneous in origin (use of intraoral needles, and all other sharp odontoiatric instrumentation) [4]. When assessing the type and mode of exposure to microorganism potentially transmitted by blood, another study conducted in the United States during 11 years, which collected 208 professional accidents, confirmed that a percutaneous route was greatly prevalent (97.5% of overall cases), compared with mucous exposure (2.9%), and other modes of contamination [5]. A prior surveillance study conducted in the United States from the year 1987 to the year 1997, assessed 504 cases of percutaneous exposure occurred in academic Dentistry and Stomatologic environment, and classified these accidents as “moderate” exposure in 52% of cases, “deep” exposure in 10% of episodes, and “superficial” exposure in the remaining 38% of cases [6]. The same paper published by Younai *et al.* [6], underlined that among the exposed personnel a greater prevalence occurred among students and in-training Professional figures (82% of overall accidents), when compared with in-charge “assistants and nurses” (12% of episodes), and in-charge Dentistry practitioners and Surgeons (only 6% of cases) [6]. As also repeated later in this review, a particular attention should be deserved to in-training Professional figures, which often suffer from a less complete technical competence, together with a reduced perception of occupational risk.

A relevant Italian epidemiological survey on professional exposure in Dentistry, which are systematically collected and examined by the dedicated “SIROH” Registry (Programma Italiano di Sorveglianza e di Controllo del rischio occupazionale da HIV ed altri patogeni a trasmissione ematica negli Operatori Sanitari, conducted at the “Lazzaro Spallanzani” Hospital of Rome, Italy), collected over 50,000 accidents occurred in the period 1986-2002, and confirmed that the percutaneous exposure is much more frequent compared with mucocutaneous one (77% *versus* 23% of episodes), and also noticed that the situation of index-patients was known in 28% of cases only, before the professional exposure. When patients' serostatus was known, the exposure to hepatitis C virus (HCV) was predominant (63% of cases), followed by hepatitis B virus (HBV) (13% of episodes), and HIV exposure (11% of cases), while in the remaining 13% of cases the index-patients had a known co-infection with

more than one agent potentially transmissible by hematogenous route (HCV, and/or HBV, and/or HIV) (personal presentation, Spallanzani Hospital, Rome, Italy, 2006).

Infection by Hepatitis B Virus (HBV)

When assessing the background from an epidemiological point of view, the occupational infection by HBV unfortunately represented a frequent event among health care professionals as a whole. A survey published in the year 2002 by Siew *et al.* [2, 3], and conducted on United States Dentistry professionals examined from the year 1974 up to the year 2001, interestingly underlined a progressive drop of serological evidence of HBV infection among health caregivers (from a mean 14% frequency during the year 1974, up to around 6% in the year 2001), thus underlying the direct and indirect efficacy of barrier prophylaxis measures, occupational guidelines, and active immunological prophylaxis (mostly represented by the large-scale introduction of anti-HBV vaccination) [2]. From the same study, in the year 2001 around 90% of United States Dentistry-Stomatological professionals were already immunized against HBV [2].

With regard to HBV infection, the index-case may be represented by a patient with an acute HBV infection, or by a subject with a chronic HBV infection (usually easy to demonstrate by a simple search of serum of HBsAg antigen of HBV). The route of professional exposure to HBV are represented by parenteral contact (either percutaneous or permucous), with blood, biological fluids containing blood, or saliva. The risk of occupational transmission of HBV is up to ten-fold greater when the index-patient proves positive at the search of serum antigen “e” (HBeAg), or he/she is viremic (i.e. the patient has a positive quantitative assay of HBV-DNA levels measured by PCR techniques). Among health care professionals who are not vaccinated for HBV or were not responsive to HBV vaccine (i.e. did not mount a sufficient antibody level after specific vaccination), the risk of transmission after percutaneous exposure ranges from 6% and 30% of cases, with the greatest risk when index-patients are HBeAg positive (37% to 62%), compared with index-patients who test HBeAg negative (23% to 37%) [7].

With regard to the mode of delivery of post-exposure prophylaxis to HBV, on the ground of the recommendations of the United States Centers for Disease Control (CDC) updated in the year 2003 [2, 7], we have to assess preliminarily the situation of each single caregivers, and each single index patient, as summarized in Table 1.

Finally, the theoretical possibility of transmission of viral hepatitis B (HBV) from a Dentistry to a patient occurred in nine different mini-clusters documented in the United States from the year 1970 to the year 1987, when a confirmed HBV infection occurred in patients cured by health care professionals who were chronic HBV carriers [2]. From the year 1987, the United States CDC did not report further episodes, so that this last occurrence is presently estimated to occur with an extremely reduced (virtually negligible) rate [5].

On the other hand, during the year 2003 an anecdotal accident which led to the transmission of HBV from one patient to another subjects has been described in an Odontostomatological environment [2].

Table 1. Viral hepatitis type B (HBV). Guidelines of occupational post-exposure prophylaxis

Health care professional	Patient	
	<i>HBsAg positive</i>	<i>HBV laboratory issues unknown</i>
<i>Not vaccinated for HBV</i>	Anti-HBV immunoglobulines*, + plus complete cycle of anti-HBV vaccination (three dosages)	Complete cycle of anti-HBV vaccination (three dosages)
<i>Effectively vaccinated for HBV</i> - with serum HBsAb antibody levels >10mIU/mL (protective levels) - with serum HBsAb antibody levels <10mIU/mL (non-protective levels)	Nothing Anti-HBV immunoglobulines*, + plus complete cycle of anti-HBV vaccination (three dosages) (should a prior vaccine cycle was not completed) Anti-HBV immunoglobulines*, with a second administration after 30 days (should a prior vaccine cycle was carried out, but the health care professional proved to be a "non-responder" to anti-HBV vaccine)	Nothing As in the case of a patient with a known HBsAg positivity, if an elevated risk of HBV infection is of concern

*Anti-HBV immunoglobulins, to be administered at 0.06 mL/Kg of body weight by intramuscular route, within 7 days after the contact.

Infection by Hepatitis C Virus (HCV)

The prevalence of chronic HCV infection among health care professionals is not significantly different *versus* that of the general population (around 1%-2% of examined caregivers) [2, 8]. As known, given the elevated diffusion of HCV infection, its high rate of chronicization (around 70% of cases), and the very frequent lack of a clinical history of an acute (i.e. icteric-symptomatic) phase, HCV infection is still underestimated in the general population, so that in a significant percentage of cases only anecdotally retrieved serum liver enzyme alterations lead to the (often late) recognition of an underlying chronic, but missed HCV infection, which is often already progressed towards more advanced hepatic disease stage.

In a literature survey conducted in a Dentistry environment on 49 patients who tested positive at the search of plasma HCV-RNA (i.e. positive HCV viremia, as assessed by a molecular biology technique of polymerase chain reaction or PCR), HCV-RNA proved present

in saliva in 35% of cases, while this percentage rose to 41% when gingival interstitial fluid was examined [9]. During 135 interviews conducted in Australia and regarding the management of different Odontostomatologic procedures, dental extraction proved to be the main determinant of iatrogenic exposure of health care professionals to HCV-infected patients (85% of cases), followed by surgical procedures carried out under general anesthesia (82% of episodes), surgery performed after local anesthesia (76% of cases), and complex Odontoiatric-Stomatologic procedures (35% of episodes) [10].

Anyway, the comprehensive risk of occupational transmission of HCV is considered quite low; for example, until the year 2002 only four anecdotal cases of anti-HCV seroconversion were registered among Dentistry practitioners in Italy, two of them occurred after conjunctival contamination with infected blood [11], and another episode after blood contact of non-undamaged skin. Needlesticks with contaminated injection needles represent the most relevant professional risk factor, for Odontostomatologic personnel too [2, 8], as well as for the caregivers as a whole. The mean risk of HCV transmission after percutaneous exposure is estimated around 1.8% of cases (range 0-10% of cases), on the ground of the available literature evidences [2, 7, 8, 12].

During a recent survey performed among 267 Brazilian Dentistry professionals, although the prevalence of HCV infection among caregivers was extremely low (0.4%) and comparable with that of the general population, a worrying lack of awareness regarding the risk of exposure to HCV (and other blood-borne microorganisms), was found in the great majority of health care personnel [13].

Taking into account that at this time we lack of both effective active and passive immunoprophylactic strategies against HCV (neither vaccines nor immunoglobulines are available), the recommended procedures after a professional accident occurred with patients with a confirmed HCV infection should include [8]:

- a screening of anti-HCV serology at baseline (mostly for medical-legal-insurance purposes);
- repeated testing of anti-HCV serology after 3-4 and 6 months;
- eventually, the search of plasma HCV-RNA (by a PCR technique), to be performed after at least 4 and 6 weeks after the occupational exposure;
- should primary HCV infection is detected, the quantification of plasma HCV-RNA viral load becomes mandatory;
- should also HCV quantitative viremia test positive, an eventual pharmacological anti-HCV treatment may be considered (under experimental basis, at this time), in order to try to reduce the risk of chronicization in the recently seroconverted health care personnel [2, 8, 14].

Infection by Human Immunodeficiency Virus, or HIV

Like in the event of exposure to hepatitis C virus (HCV), no active and passive immunoprophylaxis measures exist in the event of occupational exposure to HIV-infected patients.

Until 2001, a dedicated United States registry documented 57 cases of HIV infection presumably acquired by occupational exposure among health care givers, but no episode was registered in the Dental-Odontostomatological environment [2]. Anyway, the risk of occupational transmission of HIV infection is deemed to be very low, being estimated at an average of 0.3% (range 0.2%-0.5%) in the event of accidental percutaneous injection, around an average 0.1% (range 0-0.2%) when mucous exposure is of concern, and virtually absent in the event of exposure of non-undamaged skin. Since these data were collected before the introduction of the more potent, combined antiretroviral therapies (cART) (during the years 1986-2002 [2], it may be estimated that a further reduction of risk of transmission should stem from the enlarged use and the established efficacy of the present, highly active antiretroviral therapy (HAART) combinations, which have been widely diffused in the industrialized world since mid-1996 (12 years ago).

Although not at highly infecting concentrations, HIV is however retrievable in oral fluids, as demonstrated by the possibility to make a dosage of viral load (either HIV-RNA or HIV-DNA) in saliva in 5% to 44% of subjects with HIV disease. Such an oral viral load, although proportional to plasmatic levels, however remains highly lower than that concurrently measured in the patients' serum, and around 3-fold lower compared with that measured in the semen with the same laboratory techniques. As expected, the levels of salivary HIV viral load may be increased in the presence of local inflammatory disorders, like gingivitis, parodontopathy, stomatitis, mouth and lips ulcerations, and even more should hemorrhagic facts be of concern. The proportionally low levels of HIV salivary virus concentrations, together with the local presence of natural substances able to inhibit HIV Retrovirus (i.e. the secretory leukocyte proteinase inhibitor or SLPI, the lysozyme, and numerous other defences), continue support the concept that saliva per se cannot be considered, and is not presently referred as a vehicle of HIV infection during health care assistance [2, 15, 16].

Anyway, it remains known that the factors eventually supporting an increased risk of HIV infection transmission to health care personnel are associated with one or more of the following conditions [19]:

- needlestick with a hollowed needle;
- deep injury;
- exposure to an elevated volume of patient's blood;
- accident occurred with a needle or other sharp instrument, which appeared visibly contaminated with blood of the index patient;
- injury occurred with a needle directly positioned in a vein or artery of the HIV-infected patient;
- exposure to a patient with advanced, uncontrolled HIV disease (i.e. full-blown AIDS), and/or patient who is not under any antiretroviral therapy, or has a poorly effective ongoing anti-HIV treatment (i.e. when viral resistances to drugs are present), all conditions which may support greater plasma levels of HIV-RNA (viral load), and an increased patient's infectivity.

Interesting epidemiological data are available from the United States registry of post-exposure prophylaxis (regarding the overall cases of accidental exposure by caregivers). In a three-year period (1996 to 1998), among 492 cases of documented professional exposure to HIV, around 60% of index patients had a known HIV infection [17]. Percutaneous injuries largely predominated over mucous-cutaneous ones (85% *versus* 10%), while causative biological fluids were represented by blood in 71% of episodes, followed by other biological fluids containing blood (occurring in 13% of cases). Among health care professionals who underwent a pharmacological prophylaxis, at the time of the study conduction a triple drug combination (three different, associated antiretroviral agents given simultaneously), was carried out in 59% of cases, while a dual combination was delivered to 36% of exposed subjects, in all cases within a very short time interval after the accident (median time: 1.8 hours) [17]. Even though among health caregivers the early interruptions of antiretroviral prophylaxis were remarkably frequent (around 54% in this study, taking into account the standard, recommended duration of antiretroviral prophylaxis still fixed in 30 days), no case of HIV transmission to exposed personnel occurred, after adequate, repeated serological controls [17].

When focusing specifically on Odontoiatric-Stomatological personnel, 208 cases of accidental exposure have been registered in the United States from the year 1995 up to the year 2001 [5].

Risk procedures were predominantly represented by percutaneous exposure, with the involvement of hollow needles in the majority of events. Index patients had an HIV infection already known, or subsequently ascertained, in only 53 cases (37% of overall episodes). A post-exposure pharmacological prophylaxis has been conducted in 24 Dentistries with three associated antiretroviral compounds (cART), during a period ranging from 5 and 29 days. No case of HIV seroconversion has been registered among the whole cohort of 208 involved health care professionals [5].

In Italy, the pharmacological prophylaxis of professional contacts with HIV-infected patients of subjects suspected to be HIV-infected is periodically updated by a branch of the Italian Ministry of Health. The main indications to recommend a anti-HIV combined pharmacological prophylaxis are the following:

- accurate clinical history of the exposed caregiver, and detailed report of the dynamics of the professional accident;
- release of a written informed consent, preceded by an adequate counselling performed by the reference Infectious Disease specialists, which are available through Emergency consultation 24-hours round;
- timely initiation of anti-HIV drug prophylaxis (preferably within 1-4 hours after the accident). Such a pharmacological intervention is no longer recommended should over 72 ore have elapsed since the occupational exposure;
- accurate selection of drugs, their combination, and their dosage, which reproduce as per potency and efficacy those proposed by the most recently updated guidelines for the treatment of HIV infection (three-drug antiretroviral regimens, or cART) [18];

- the duration of occupational chemoprophylaxis is fixed at four consecutive weeks, with periodical hematological-biochemistry laboratory controls (to be performed at the baseline, and every 10 days during the pharmacological prophylaxis);

Table 2. Post-exposure chemoprophylaxis of health care professionals, with regards to HIV infection (year 2008)

Mode of exposure	Post-exposure prophylaxis
- injury caused by needle or other sharp instrumentation	- recommended
- conjunctival contamination	- recommended
- contamination of non-undamaged skin, or mucous contamination	- to be considered
- wound caused by human bite	- to be considered
- contamination of non-undamaged skin	- not recommended
Index patient	Profilassi post-esposizione
- patient with known positivity for HIV infection	- recommended
- patient with unknown situation regarding HIV infection, or subject who refers to be HIV-negative	- to be considered
- patient with unknown situation regarding HIV infection, or whose situation is not available	- to be considered
- patient with a known negative HIV testing	- not recommended

The guidelines widely applied for the post-exposure prophylaxis after an accident possibly involving HIV-infected index patients are stratified according to the mode of exposure, and the known conditions of index patient [18], as briefly summarized in Table 2.

Since the early introduction of highly active antiretroviral therapy (so-called HAART), which was available from mid-1996, the majority of HIV-infected individuals (presently around 80% of them), is treated with a cART, usually including at least three different, associated antiretroviral molecules. The availability of HAART, while significantly modified the natural history of HIV disease leading to a sharp drop of morbidity and mortality rates, concurrently contributed to a progressive increase of emerging and spread of drug-resistant HIV viral strains, which often become unsensitive to more drugs and multiple drug classes. This last situation leads to a prompt consideration of resistances also when a post-exposure prophylaxis has to be considered, so that a “standard” combination, or a regimen selected on the ground of eventual needs of the exposed caregiver (i.e. tendency to develop anemia, eventual kidney or liver abnormalities, ongoing pregnancy, and so on), are now overcome by regimens which should be “tailored” as far as possible also on the ground of the cART performed by the index patients, the levels of patient’s adherence to his/her prescribed cART, the level of attained virological-immunological success, and eventual informations regarding suspected or established viral resistances of HIV against the drugs administered during patient’s lifetime. The epidemiological survey conducted at the time of occupational exposure should therefore include (when possibile) the knowledge of antiretroviral drugs taken by the

index patient at the time of accident, their efficacy (depending on measured plasma HIV-RNA levels), the grade of patient's compliance to recommended therapy (since a low adherence may support the emergence of viral resistances), and the eventual availability of a pharmacological HIV resistance testing [19, 20].

A anticipated, anti-HIV drug prophylaxis, when indicated after a risky professional exposure, is still recommended to be 30-day long, although it seems intuitive that the maximum protective activity is concentrated during the first hours and the first day after exposure to HIV infection: hence, the importance of starting prophylactic measures as soon as possible. Infectious Disease specialists are committed to the selection (and eventual modification) of the specific pharmacological regimen, as anticipated above; among over 20 different antiretroviral drugs presently available. The treatment protocol should be illustrated and shared with the exposed caregiver, and the subsequent clinical and laboratory monitoring should be carefully planned.

Finally, a short notation on the virtual possibility of HIV infection transmission from the health care professional to his/her patients, which is estimated to be an extremely rare event, which however was stressed by an anecdotal report which shed light on a probably voluntary spread of HIV infection to a group of six patients occurred in Florida (USA) in the year 1990, by a single Dentistry specialist (the so-called "Kimberly case"), documented also through the analysis of the viral genomic sequence, which proved the same in the caregiver and in the six infected patients [21].

Microorganisms Transmitted by Saliva and Respiratory Secretions

This broad category of microorganisms include some pathogens burdened by a possible occupational exposure, like i.e. *Mycobacterium tuberculosis*, Streptococci and Staphylococci, *Neisseria meningitidis*, Influenza and Parainfluenza viruses, Herpes simplex virus (HSV), Cytomegalovirus (CMV), Epstein-Barr virus (EBV), Adenovirus, Rhinovirus, Paramyxovirus, and Rotavirus [22, 23].

The potential routes of transmission from patients to health care professionals include contacts with saliva of respiratory secretions, by direct contact, indirect contact, and by inhalatory route. Among factors which may influence the risk of occupational transmission, the prevalence of infection(s) in the local, general population, the microbial load retrievable in respiratory secretions, the mode of spread of respiratory secretions (i.e. cough, sneezes), the presence of potential vehicles of transmission (i.e. instrumentation, working surfaces, dust, aerosol), the virulence grade of eventual causative microorganisms, the amount of infected material responsible for occupational exposure (infecting load), as well as the grade of susceptibility and the immune state of the host (health care professional in this event, all these conditions may play a significant role, and should be carefully considered.

A short reference is dedicated to the respiratory tubercular infection.

Tuberculosis

Also as a consequence of the recent epidemiological mutations which involved the majority of developed countries, *Mycobacterium tuberculosis* shows an increasing importance in the general population, and even more among subjects which are immunocompromised at some grade [24, 25].

Patients with active, clinical pulmonary or laryngeal tuberculosis may spread mycobacteria via the droplets of respiratory secretions (diameter: 1-5 μm), diffused after cough or sneezes. These particles may remain in suspension in the room air for a number of hours, and the particular wax-including cell walls of mycobacterial organisms support their slow soil deposition. Moreover, mycobacteria may survive in the environment (i.e. dust) for weeks or event months, and may be transmitted by inhalation to a susceptible host even after an apparently prolonged time.

In the Dentistry-Stomatological practice, only one case of occupational tuberculosis has been documented in the United States until the year 2003 [15, 24], so that the risk of trasmission of this mycobacterial disease by inhalatory route from a patient to an Odontoiatric caregivers is estimated to be very low in frequency, as indirectly confirmed by a low rate of positive tuberculin skin testing (Mantoux intradermal reaction) among Odontostomatological personnel as a whole [5, 22, 25].

As in the event of any other health care professional, the measurs of control of occupational transmission of tuberculosis include the implementation of a targeted epidemiological and clinical surveillance, an early recognition of patients with active pulmonary tuberculosis and their appropriate isolation, an adequate formation and training of caregivers with regard to the systematic resort to the use of filter-equipped facial masks (N-95 model), when a suspected case is of concern [22, 25] (refer also to Table 3), and the timely assessment of exposed personnel who shows some suspect signs and symptom (i.e. cough persisting since at least three weeks, with or without fever, anorexia, asthenia, night sweats, weight loss, and eventually hemoptysis).

Table 3. Devices to be used appropriately for individual safeguard

Individual safeguard devices	Characteristics
Disposable surgical mask, protecting either nose and mouth	It confers protection against particles whose size (diameter) is greater than 5 μm
Facial mask (filter-equipped), belonging to the N-95 type	It confers protection against particles whose size (diameter) is lower or equal to 5 μm
Protective eyeglasses	
Disposable, protective gowns	
Disposable gloves	To be always employed when surgical procedures, or other invasive medical interventions, are carried out

When urgent Odontoiatric-Stomatological care has to be delivered to a patients with active, bacillary pulmonary tuberculosis, the assistance should be delivered in a appropriate environment which guarantees respiratory isolation (rooms with adequate filtering and

turnover of air volumes in an established time), and making strict use of all devices of individual protection, including disposable gloves, glasses, protective gowns, and facial masks with type N-95 filters [15, 25].

As known, the common surgical masks do not ensure protection against transmission of respiratory tuberculosis to other patients and the health care personnel.

Microorganisms Transmitted by Water

Water reservoirs and pipelines which move water supplies (i.e. irrigators, pipes, syringes, tartar ablaters), may be easily colonized by bacteria, fungi, and protozoa (sometimes able to overcome some common disinfection procedures). In particular, bacteria tend to adhere and growth on the internal surface of the pipes, often protected by a polysaccharidic layer (which is part of the superficial glycocalix of a number of bacterial species). As a consequence, a biofilm which continuously increases the resident bacterial population is typical of superficial waters, and this bacterial reservoir may be transmissible to patients and health caregivers, too [5]. In the majority of cases, saprophytic or commensal organisms are of concern, which however may become frankly pathogenic when subjects with underlying, chronic, severe disorders, immunocompromised hosts, or subjects with damaged cutaneous/mucous barriers are assisted.

Among the numerous microorganisms which are potentially present in devices which contain or convey water, the following are the most frequent and/or the most relevant for human pathology [3, 23]:

- *Legionella* spp.;
- *Pseudomonas aeruginosa* and *Pseudomonas* spp.;
- Non-tuberculosis mycobacteria (so-called “atypical mycobacteria”);
- *Shigella* spp.;
- *Acinetobacter* spp.;
- *Stenotrophomonas* (formerly *Xanthomonas*) *maltophilia*;
- *Guardia lamblia*;
- *Cryptosporidium parvum*.

The route of transmission of the above-mentioned microorganisms spread through superficial water involve either the ingestion or a direct contact with water, contacts with contaminated instrumentation, and inhalation of aerosolized particles. Dental procedures performed with high-speed instruments tend to expose health caregivers to possible splashing in nearly 90% of cases, and over 50% of the stains are invisible to the naked eye, according to recent 2008 studies [26, 27]. In particular, contamination of both air and surfaces by blood particulate may reach 100% of cases, should procedures leading to extensive aerosols of body fluids are performed.

Some surveillance studies carried out on health care personnel of Odonto-Stomatology units located in different geographical areas, alteration of resident nasal flora has been demonstrated, as well as an increased prevalence of a positive serology against *Legionella*

spp. among caregivers, compared with the general population. From a practical point of view, only anecdotal reports of documented cases of occupational infections caused by these pathogens have been registered: the majority of these episodes involved subjects with some form of immunodeficiency, and an elevated level of microbial concentration in examined water sources (over 500 CFU/mL) [Centers for Disease Control, and American Public Health Association, 2003] [3, 7].

When focusing our attention on legionellosis, a specific survey has been conducted in 28 United States Odontostomatology studies: a combined examination of water reservoirs and water distribution pipes, led to the retrieval of specimens positive for *Legionella* spp. in 32% of cases, and *Legionella pneumophila* even in 92% of specimens examined with direct immunofluorescence technique and/or PCR [28]. In the same literature study, the concentration of Legionellae in water reservoirs and mains tested particularly elevated (above 1,000 CFU/mL) in 36% of events, when *Legionella* spp. was retrieved [28].

When considering *Pseudomonas aeruginosa*, this last gram-negative organism (dangerous due to the severity of respiratory and urinary tract infections, and its frequent, enlarged antibiotic resistance pattern), has been retrieved in 5.5% of water supplies examined during a Danish study performed in 327 different reservoirs and distribution pipes of a large number of Odontoiatric-Stomatologic studies and clinics [29]. However, the possibility of nosocomial transmission of *Pseudomonas* spp. to patients undergoing dentistry-stomatological cures remains low, as suggested by an anecdotal report of the year 1996, when one single case of *Pseudomonas aeruginosa* pneumonia was described from Denmark, in a highly predisposed patient suffering from cystic fibrosis, who previously underwent dental extraction [29]. The authors documented a genotypic relationship between bacteria isolated from respiratory secretions of the involved patient, and those retrieved from water and instrumentation of the Odontoiatric clinic where the dentistry intervention had been performed [29].

In order to increase the safety index of the instrumentations containing or working with water supplies, usually employed in Medical and Odontoiatric-Stomatological studies, according to the recommendations of the United States Centers for Disease Control [3, 7], from a practical point of view it appears useful:

- let flow down the water for a sufficiently long time, before using instrumentation and devices, early in the beginning of each working day;
- to employ chemical-physical treatments for basic water disinfection;
- to make a systematic use of appropriate micro-filters;
- to make a systematic use of anti-reflow valves in order to avoid any sort of water stagnation;
- to follow adequate hygienic procedures during patients treatments (i.e. let flow down both air and water for at least 20-30 seconds);
- rely on sterile water or saline solution during all surgical procedures;
- to monitorize periodically the bacterial concentration in reservoirs and water pipes and mains of all studies where Dental and Odonto-Stomatological procedures are practiced.

Other Infections Potentially Related to Occupational Transmission Routes

Transmissible Spongiform Encephalopathy

The transmissible spongiform encephalopathies are neurodegenerative disorders characterized by a rapidly progressive and fatal evolution, which may involve animals and humans, and are caused by protein-composed infectious agents (the so-called “prions”), which are highly resistant to the common disinfection and sterilization procedures. Not transmissible by aerial route, these disease are generally classified into: animal spongiform encephalopathies (scrapie, mink encephalopathy, feline encephalopathy, exotic ungulate encephalopathy, elk devastating encephalopathy, and bovine spongiform encephalopathy, the so-called “mad cow disease”, or BSE), and human forms (Kuru, Gerstman-Straussier-Scheinker disease, familiar fatal insomnia, Creutzfeld-Jacob disease, and the so-called “novel variant” of Creutzfeld-Jacob disease) [30].

The human spongiform encephalopathy of potential iatrogenic interest is the Creutzfeld-Jacob disease, which is nosographically classified into two variants:

- a sporadic form (responsible of around 85% of observed episodes);
- a familiar form (found in around 10-15% of cases);
- possible, rare iatrogenic forms, potentially transmissible through neuro-surgical instrumentation and contaminated intracranial electrodes, hypophyseal hormones extracted from affected patients, and implants of cornea or dura mater obtained from patients deceased due to Creutzfeld-Jacob disease.

As widely known, the so-called “new variant” of Creutzfeld-Jacob disease has been detected and investigated since the year 1996. It is transmitted from bovines to humans, mostly by alimentary route [30].

The epidemiological data available to date did not demonstrate the transmission of these spongiform encephalopathies during Dentistry and Odontostomatological procedures. Furthermore, infecting prions were not found in blood, saliva, oral cavity tissue, and dental pulp of patients affected by a confirmed Creutzfeld-Jacob disease [22, 23, 31], so that the risk of transmission associated to Odonto-stomatological procedures is deemed to be extremely low [22]. Anyway, when suspected cases are of concern, disposable instruments should be used, and extremely potent sterilization procedure applied (i.e. NaOH 1-normal solutions for at least one hour, followed by an autoclave passage at 134-138°C for at least 20 minutes).

Strategies of Prevention of Occupational Infections

The interruption of the chain of potential infection transmission play an absolutely crucial role when assessing the prevention and safeguard procedures of health care professionals [1-3]. This strategies includes:

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- the adoption of an appropriate environmental hygienic standards;
 - the application of adequate measures of personal hygiene and security;
 - a containment of unexpected “breakdown” risks, indirectly connected to logistic and organization problems, overcrowding, and so on;
 - correct and constant use of individual protection devices [24] (i.e. masks, eyeglasses or visor masks, gloves);
 - systematic application of adequate procedures of disinfection and sterilization of all instrumentation;
 - maximum attention paid to the procedures of collection and elimination of needles and disposable sharp instruments (i.e. resort to rigid containers, incineration procedures, and so on);
 - application of aseptic assistential techniques and procedures;
 - systematic use of liquid/air aspirators (in order to minimize the formation of aerosolized biological fluids);
 - permanent epidemiological surveillance, and standardized monitoring of eventual professional accidents;
 - implementation of periodical screening procedures of health care givers, and early diagnosis of patients with suspected infections, transmissible diseases;
 - rely on all possible strategies of immunoprophylaxis (i.e. wide use of available vaccination procedures).

In fact, when considering that the majority of patients with infectious disorders potentially transmissible to health care personnel who required Dentistry and Odontostomatological interventions, is asymptomatic or paucisymptomatic, it may frequently happen that these subject may ignore or voluntary hide to assistential staff. As a consequence, it becomes mandatory to always consider blood and biological fluids as potentially infected or infecting. It is therefore necessary to systematically apply the standard safeguard procedures from any kind of parenteral contact with blood and biological fluids (i.e. saliva, respiratory secretions, biopsy specimen), and to appropriately protect non-undamaged skin and mucous surfaces (i.e. conjunctives, oral cavity and nasal mucous membranes). Finally, its always remains useful to remind the crucial importance of careful and frequent hand washing with water and soap or antiseptic solutions, either before, and after using gloves.

All Dentistry-Odontostomatological instrumentation (and all non-disposable surgical instrumentation as a whole), needs accurate cleansing and sterilization. All health care professionals who act in the Dental-Stomatological specialties and sub-specialties are and should be considered surgeons called to perform potentially invasive procedures.

With regard to the potential risk of transmission of infectious agents, Odontostomatological instruments (and surgical instruments as a whole), may be classified as:

- critical, when it includes instruments able to penetrate bone and soft tissues;
- semi-critical, should the relevant instruments do not penetrate body tissues, but have contact with superficial mucous membranes;
- not critical, when instrumentation is used exclusively over undamaged skin surfaces.

As anticipated, the prompt availability and the systematic and correct use of all individual protection devices (also defined as personal protective equipment, or PPE), play a fundamental role during clinical procedures which encompass a potential exposure to blood, body fluids, or secretions, even when they are dispersed in an aerosolized form. The different devices to be employed according to the different clinical scenarios are briefly summarized in Table 3, together with their most relevant characteristics.

A recent survey regarding the resort to individual protective equipment conducted in Parma (Italy) through 122 interviews of Dentistry specialists, demonstrated an elevated degree of awareness of these health care professionals against the problem of protection against occupational infectious disease [30]. In fact, this study demonstrates that a regular use of gloves regarded 98% of medical and surgical Dentistry-Odontostomatologic procedures, a regular use of masks rated 95% of cases, that of eyeglasses 94% of cases of all caregivers potentially exposed to body fluids [2].

During a series of recent interviews carried out in a qualified, academic Odontoiatric-Stomatological environment in Palermo (Italy) the risk exposure to hepatitis B infection and the grade of HBV vaccine coverage were inversely proportional to the level and duration of professional practice [20], thus underlying that student, trainees, and residents may be exposed to increased risks, and an appropriate counselling and training aimed to increase awareness of these relevant problems is still strongly needed [31]. In fact, two recent United States surveys [32, 33], underlined that just during the study course and practical training, students or trainees tend to underestimate the risks and problems related to the professional exposure as a whole, and also to miss the report of “accidents” (generally needlesticks or other instrumental injuries), since they deemed these events not relevant (around one third of cases) [33]. The frequency of underreporting was greater in health care givers of male gender [33], and also during the first years of study and professional training [32, 33].

In the event of professional accident, regardless of the different recommendations reported above, which are scheduled according to the different potential causative pathogens [2, 3], we underline the need to always pursue the following passages:

- when a percutaneous lesion is of concern, it is necessary to accurately wash the exposed area with water and soap or disinfectant solutions;
- in the event of exposure of non-damaged skin to blood and/or biological fluids, it appears sufficient to accurately wash the exposed area with water and soap or disinfectant solutions;
- when a conjunctival exposure to blood and/or biological fluids is of concern, we recommend to wash and rinse the eyes with water and saline solutions;
- in the event of oral contact or ingestion of blood and/or biological fluids, it is necessary to immediately wash and rinse repeatedly the oral cavity with water and saline solutions;
- in every case, it is recommended to predispose and fill an accurate report indicating location, date, and hour, type of professional exposure, name of index patient, immunoprophylactic situation of the involved health care professional, adopted procedures, and scheduled follow-up;

- the notification of professional accident should be reported according to the different rules provided by National Services of Health;
- the different measures of microbiological diagnosis and post-exposure prophylaxis (i.e. serological controls, vaccinations, immunoglobulin administration, pharmacological chemoprophylaxis, and so on), should be performed in the events and according to the recommendations depicted above, which follow the updated international recommendations in this field;
- internal guidelines which predispose a univocal pathway, which offer a more suitable, an easily recognizable, and a more rapid algorithm for the health care professional involved in an accidental exposure, should be implemented and continuously updated on the ground of present regulations, the evolution of scientific knowledge, and the local network of competences and responsibilities (i.e. involvement of Emergency Rooms, Occupational Medicine, Preventive Medicine, Infectious Diseases, Microbiology, and so on).

As largely presented above, and according to the United States Centers for Disease Control recommendations, should specific contraindications are absent, all health care personnel which works in the Dentistry-Odontostomatological environment, should receive the following active immunoprophylaxis measures (vaccinations):

- type B hepatitis (HBV);
- measles, rubella, and epidemic parotitis;
- Influenza virus;
- Varicella-zoster virus.

Conclusion

As per each academic and professional institution, it appears mandatory that also in the Dentistry-Odontostomatology field, all data regarding the potential, accidental exposures to pathogens are reliably collected, and periodically monitored and analyzed, in order to establish a permanent control with regard to the adoption of all the recommended protection measures and prophylactic strategies, the following of international and local guidelines in this field, in order to ameliorate the level of care delivered to patients, and to strengthen the formation process of all future health care givers, also in the management of professional risk, due to accidental exposure to pathogenic microorganisms. A systematic collection and analysis of all updated, available figures, may be a solid basis to assess the type, location, time variations, involved caregivers, their grade of formation and competence, and confidence with the appropriate and timely adoption of all specific recommendations in this area. On this ground, the possibility to predict and prevent professional exposures to infectious agents is expected to increase, by implementing a uniform educational pathway and a technical-practical knowledge, which has to enter the heritage of theoretical and technical-practical knowledge which are part of the formation process delivered by any recognized and certified academic and professional institutions.

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Chapter 7

Cross Infection Risk in Dental Practice: Evaluation of Environmental Contamination and Personnel Knowledge and Behavior in Italian Public Dental Practices

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Abstract

Infection hazard linked to dental practice is not a recent problem. Some studies have shown that the environment and personnel procedures play an important role in this context. The Working Group “Hygiene in Dentistry” of the Italian Society of Hygiene, Preventive Medicine and Public Health (SItI) deals with infection prevention in dental practice. One of its aims is to evaluate hygienic conditions and risk awareness in public

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dental services. A study of knowledge of cross-infection hazards and behavior in dental personnel was carried out by questionnaire in some Italian cities. It showed that dental personnel do not follow completely the main procedures for infection control. Environmental microbial contamination in some Italian dental clinics was evaluated. The results showed some critical points in the contamination of water, air and surfaces of the dental surgeries studied. In conclusion, some aspects of daily dental practice may represent a concern for cross infection; therefore, it seems to be absolutely necessary to promote training programs for personnel on the correct use of control procedures in work environments, as well as to draw up a good practical guide for the management of dental outpatient departments.

Background

Infection hazards linked to dental practice are not a recent problem. Many infectious agents, including viruses [Hepatitis B virus (HBV), Hepatitis C virus (HCV), Human Immunodeficiency virus (HIV), Herpes Simplex virus, Epstein–Barr virus and Cytomegalovirus] and bacteria (*Streptococcus pneumoniae*, *Mycobacterium tuberculosis*, *Klebsiella pneumoniae*, *Escherichia coli*, *Legionella pneumophila* and *Pseudomonas aeruginosa*), may be transmitted in this context. Some studies have shown that the environment (water, air and surfaces) can play an important role in infection: water stagnation, biofilm production and lack of disinfection in dental unit water systems (DUWSs) promote the proliferation of microorganisms [6, 9, 41, 47]. In addition, ablators, turbines and air–water syringes may nebulize the saliva and microorganisms contained in the patient’s mouth, with the consequent contamination of the surrounding air and surfaces [16]. This suggests a potential risk of infection, especially from water, particularly in patients who are immunocompromised by drug therapy, alcohol abuse, systemic diseases and old age [31]. Some authors have declared that there is no evidence that DUW is harmful to patients, even though it is undisputed that lower water contamination carries a lower risk to patients, and exposure to water that contains high numbers of bacteria violates basic principles of clinical infection control [8, 20]. Moreover, there may be an occupational hazard because of much greater exposure of the staff [3, 5, 15, 25, 26, 30, 42, 43]. Therefore, in order to minimize the hazards linked to dental practice, various cut-offs of total viable count (TVC) in DUW have been proposed. In 1995, the American Dental Association (ADA) stated that the TVC must be ≤ 200 CFU/mL, which was based on the quality assurance standard established for dialysate fluid [ADA 1996] [1]. The CDC has reported that, for coolant water used in non-surgical dental procedures, the TVC must be ≤ 500 CFU/mL [8], as established by the US Environmental Protection Agency for drinking water and the ADA in 2007 [2].

A multicenter study that assessed the microbiology of DUWSs in general dental practice across seven European countries has shown that a substantial proportion has high levels of microbial contamination, which highlights the risk of occupational exposure and cross-infection during dental practice [44].

Italy did not participate in that study and only a few papers on environmental microbial contamination in dental surgeries and cross-infection risk were present in the literature [22, 38]. Since 1996, the Working Group “Hygiene in Dentistry” of the Italian Society of

Hygiene, Preventive Medicine and Public Health (SItI) has dealt with infection prevention in dental practice. One of their projects evaluated the hygienic conditions and risk awareness in public dental services.

We evaluated microbial contamination of water, air and surfaces in some dental clinics in Italy and investigated knowledge of cross-infection hazards among dental personnel and their health behavior [7, 21, 23, 24]. In the first analysis, we employed environmental microbial monitoring, while risk awareness was studied by questionnaire. Some of the results obtained are reported here.

Methods

a. Personnel Knowledge

The study was carried out in 15 public university or hospital dental clinics (Ancona, Bologna, Brescia, Bari, Cagliari, Ferrara, Genova, L'Aquila, Milano, Modena, Perugia, Roma "La Sapienza", Roma "Università Cattolica", Sassari, Verona) and 474 dentists were voluntarily enrolled.

The aim of the study was to obtain information about the knowledge of hygienic risks and measures to minimize them. The questionnaire was anonymous and included questions about:

1. personal information: age, sex, degree, years of activity, relationship between private and public work;
2. technical information: number of dental units per room, and employ of steam autoclaves, stoves and air purifiers;
3. health problems that occurred during activity (punctures, injuries and infections) and knowledge of infection risks for dental personnel and patients (transmissible diseases and hazardous procedures);
4. preventive measures for self-protection against infection risks: immunization and individual protection systems;
5. preventive measures for patient protection against infection risks: sterilization and disinfection of instruments, and environmental and unit water decontamination.

The manager of each clinic was reached by phone for presentation of the project. On the selected day, the questionnaires were delivered directly to the dental operators to whom instructions for the compilation were done. The questionnaires were collected after 2 weeks.

Data obtained were analyzed through the SPSS advanced statistics 7.5 software.

b. Environmental Evaluation

The study was carried out in 102 dental units (87 university and 15 public facilities) at 64 dental clinics in eight Italian cities (Bari, Brescia, l'Aquila, Modena, Napoli, Perugia, Roma

and Sassari). Participation in the study was on a voluntary basis. All the participants collected specimens on Monday morning. Water specimens were collected from dental units (cup fillers and/or air–water syringes) at the start and end of morning practice (generally 08:00 and 13:00 h). Air and surfaces were sampled before the start (T_0 , empty room) and during clinical practice (T_1 , when the dentist, assistant and patient were present). In addition, on the same day, 91 water samples were collected from the washbasin taps at 08:00 h.

b.1. Evaluation of Water Microbial Contamination

All analyses were performed in conformity with Italian law [11], which complies with the European Council Directive 98/83/EC of 3 November 1998 [10]. The following parameters were determined:

1. Total viable count (TVC) at 22 and 36°C. In order to calculate the percentage exceeding safety levels, a threshold value of 20 CFU/mL at 36°C and 100 CFU/mL at 22°C was considered, in accordance with Italian law [11]; moreover, a threshold value of 500 CFU/mL was considered, as indicated by the CDC in 2003 [8];
2. Total coliforms and *Escherichia coli* presence. Absence of both counts in 100 mL was required [11];
3. In addition, the 87 university DUWS were tested for *Pseudomonas aeruginosa* and *Legionella* spp. A 1 liter specimen was collected by mixing together an equal volume of water from all water points of each dental unit (ablators, high- and low-speed handpieces, air-water syringes and cap fillers). Absence of bacteria in 250 mL samples was required [11].

b.2. Evaluation of Microbial Air Contamination

Microbial air contamination was assessed by active sampling using the surface air system (SAS) to determine the number of CFU/m³, and by passive sampling using settle plates, 9 cm in diameter, exposed for 1 h, to determine the index of microbial air contamination (IMA) [32]. During the sampling, windows and doors were kept closed. The TVC was determined on Plate Count Agar.

The SAS was used to collect 180 L air in 1 min, near the dental unit, at 130–150 cm above the floor; after which, plates were incubated for 48 h at 36°C, and the number of CFU was adjusted using the conversion table provided by the SAS producer and reported for 1 m³ of air. The threshold value was assessed at 180 CFU/m³, as recommended for conventional ventilated environments [27].

To determine the IMA, expressed as CFU/plate/h after 48 h at 36°C incubation, Petri dishes (diameter 9 cm) that contained solid nutrient medium were left open to the air for 1 h at 1 m above floor level and at least 1 m from any relevant obstacle. A threshold of 25 was considered adequate [32, 36].

Overall, 78 air samples were collected (46 using SAS and 32 using settle plates). As a rule, the air sampling was performed in the middle of each surgery, in a position near the head of the patient. When two or more samples were taken because of surgery size, the mean value was used.

b.3. Evaluation of Surface Microbial Contamination

Microbiological analysis of the surfaces was performed using membrane filters (Sartorius SM 138 06AC, Ø 47 mm, 17.34 cm², 0.45-µm pores) to determine microbial accumulation (MA) [37]. In order to calculate TVC, one sterile membrane was pressed with digital pressure for 30 seconds, using sterile gloves, on each surface to be controlled. The membrane was directly collected using sterile tweezers and placed on sterile, dehydrated culture medium previously moistened with 3 mL sterile distilled water. A total of 111 samples from the countertops and 110 from switches were collected. The results for MA were expressed as CFU/cm²; a value of 1 CFU/cm² was considered acceptable [36].

b.4. Statistical Analysis

The statistical analysis was machine oriented, i.e., no clustering analysis was performed for multiple units in any one dental surgery. As a result of the skewed distribution of data, a logarithmic transformation was applied. Differences between transformed means of T₀ and T₁ counts were evaluated using Student's *t* test for paired comparisons. If a threshold was reached, prevalence was calculated as the proportion of values that exceeded the cut-off. Independence between categorical variables was tested using Fisher's exact test. The McNemar test was applied for paired comparisons. The possible interference between the presence of *P. aeruginosa* and *Legionella* spp. was tested via Fisher's exact test. *p*<0.05 was considered statistically significant.

Results

a. Personnel Knowledge

Four hundred and seventy-four anonymous questionnaires were distributed and 374 of them were collected, with an overall return rate of 78.9%. For all the questions, the percentage of answers obtained was higher than 95%.

The mean age was 40 years (SD 9.7; range 24–68). The length of professional experience was 12 years on average, and the mean percentage time dedicated to public practice was 50.1%. There was a higher prevalence of male dentists (72.9%) and of medical doctors (71.2%).

Overall, the public dental clinics had 137 departments and 430 dental units, with a mean of three dental units per department. In 59.4% of cases, the dental units were in independent rooms. Among the dental clinics, 77.5% had dedicated rooms for warehousing, 57.1% for storage of sterile materials, 58.3% for dental technicians, and 66.5% for washing, disinfection and sterilization. 92.8% of dental clinics had an autoclave or chemiclave for sterilization. Other instruments were stoves (20.9%), quartz sterilizing systems (39.3%) and microwave sterilizing machines (6.1%). High (76%) and low (84.3%) aspiration systems, air purifiers (12.5%) and air conditioners (67.9%) were present; 79.9% of taps were operated by lever, photocell or pedal, and in 15.4% of clinics, towels were used. Only in 27.3% of clinics were the phones equipped with a speakerphone or cordless earphones. 48.2% of dental units were equipped with valves against back-flow, and only 13.1% had systems for the minimization of

bacterial counts in water. It has to be stated that the number of those who did not respond to the questions about the availability of systems for infection prevention was often high.

Injuries from needles or cuts occurred frequently and 51.3% of subjects reported at least one wound in the last 5 years. This was probably caused by the practice of touching the needles after treatment, as reported by 44.1% of the operators. Although the frequency of wounds was high, the resultant onset of infectious diseases was only reported by 5.6% of those interviewed (mainly hepatitis B). Infections that were considered to be easily transmissible in dental care were viral hepatitis (42.4%), AIDS (25.1%), tuberculosis (12.0%), herpes (9.4%) and influenza (3.7%). Oral surgery was considered the most hazardous procedure.

67.3% of dentists considered their knowledge of infection risk to be sufficient and 26.2% considered it to be high. The main sources of information were Italian journals on dentistry (39.3%), university courses (21.3%), post-graduate courses (17.4%) and English-language journals on dentistry (13.9%). The majority of dentists was immunized against HBV, but only 65.2% verified their status, and other vaccine use was not very widespread; only 34.1% was vaccinated against tuberculosis, tetanus and/or influenza. However, 73.8% of operators performed periodic serological diagnostic controls for HBV, 68.7% for HCV and 61.4% for HIV (Table 1).

Table 1. Percentages of dentists who were immunized or who used other prevention measures

Prevention measures	%
• vaccination against HBV	83.3%
• seroconversion control against HBV	65.2%
• periodical controls	
HBV	73.8%
HCV	69.7%
HIV	61.4%
other vaccinations	34.1%
Passive protection	
gloves	83.7%
glasses	72.7%
two-layer covers	66.0%
surgical sheet	39.0%
three-layer covers	36.2%
bonnet	26.2%
double gloves	23.3%
disposable gowns	27.3%
upper gowns	12.6%
hand washing before and after treatment	73.2%

Gloves were used regularly by 83.7% of subjects, protective glasses by 72.7%, two-layers covers by 66%, sheets for surgery by 39%, bonnets by 26.2% and disposable gowns by 27.3%. Finally, not all the dentists declared a change of disposable covers during treatment,

and only 73.2% washed their hands properly with cleaning products or with soap and disinfectant compounds before and after each treatment.

Autoclave checks were performed with internal indicators in 28.3% of cases, external indicators in 49.7%, weekly spore tests in 43%, and daily Bowie–Dick tests in 19.5% of cases. DUW was filtered (42.5%), demineralized (27.8%), sterilized for invasive procedures (6.1%), disinfected (5.6%) or not treated (12%). Decontamination of DUW lines was carried out in 68.6% of cases, utilizing phenol (29.3%), sodium hypochlorite (16.3%) or glutaraldehyde (7.8%); aspirator pipes were disposable in 97.3% of cases. The disinfectants most utilized were sodium hypochlorite (15.4% for the devices, 20.7% for the surfaces and 13.1% for the buttons), and glutaraldehyde (18.1% for the devices, 8.3% for the surfaces and 14.1% for the buttons) (Table 2). Percentages of not-responding about these questions were quite high, with values until 39.7%.

Among chemical products, glutaraldehyde (28.8%), silver amalgam (16%), and liquids for radiography (14.3%) were considered toxic. The 24% of subjects declared at least an accidental contact with these compounds during their activity. Contaminated devices and instruments were washed and disinfected (30.5%), disinfected (16.6%) or washed (21.1%) only, or were not treated (6.4%).

Heat-sensitive materials were cleaned properly and disinfected in 58.9% of cases. In 13% of cases, the disinfection preceded the cleaning, in 9.6%, only disinfection was applied, and in 2.8%, only cleaning was carried out. Between patients, buttons and air–water syringes were disinfected in 67.1% and 71.4% of cases, respectively, but the disinfection of implants before and after their positioning was performed in only 46.5% of cases. Exposed surfaces were treated mainly with disinfectants (64.7%) or less frequently, covered with polyethylene films (28.3%).

Finally, patients with HIV (80.2% of cases), HBV (82.4%), HCV (82.7%), herpes (60.6%) and tuberculosis (77.2%) were treated at the end of the day and with major precautions. However, 8.7% of clinics could not manage properly subjects with HIV, 5.6% those affected by tuberculosis, 4.1% those affected by hepatitis, and 2.3% those with herpes.

Table 2. Percentages of answers about disinfectants employed

Disinfectant	devices	surfaces	buttons
Sodium hypochlorite	15.4%	20.7%	13.1%
Quaternary ammonium salts	9.2%	14.9%	11.8%
Glutaraldehyde	18.1%	8.3%	14.1%
Ethanol	5.2%	12.5%	9.6%
Phenol	7.2%	9.8%	5.7%
Hydrogen peroxide	10.7%	2.6%	1.0%
Chlorexidine	3.2%	4.9%	5.0%
Formaldehyde		1.2%	
	(NR = 31.0%)	(NR = 25.1%)	(NR = 39.7%)

NR = non-responding.

b. Environmental Evaluation

TVCs at 22 and 36°C from water samples are shown in Table 3. T_0 -logarithmic means were higher than T_1 at 22 and 36°C for cup fillers (1.6 vs 1.3, $p=0.16$ and 1.7 vs 1.2, $p=0.02$) and for air–water syringes (1.8 vs 1.4, $p=0.03$ and 1.7 vs 1.2, $p=0.01$). At the same time, the proportion of samples with higher levels than those recommended by Italian law was higher at T_0 than at T_1 at 22 and 36°C. In fact, these proportions decreased significantly at T_1 for all parameters (McNemar test: $p<0.05$), except for cup-fillers at 22°C, for which the reduction was not significant (McNemar test: $p=0.19$). No samples exceeded the CDC 2003 threshold value of 500 CFU/mL (data not shown). The TVCs from tap water were lower than those from dental units at T_0 ($p<0.001$, data not shown). Total and fecal coliforms were not found.

Table 3. Mean levels and standard errors (se) of TVC at 22° and 36 °C (cfu/mL) from water samples, prevalence of samples with bacterial levels above the threshold levels established by Italian law (21) (no samples exceeded the CDC 2003 threshold value). Statistical analysis of differences between T_0 and T_1 (t-test for paired samples for means and McNemar test for proportions)

Cup fillers						
	22 °C			36 °C		
	T_0	T_1	statist. anal.	T_0	T_1	Statist. anal.
Logarithmic mean	1.6 (se=0.15)	1.3 (se=0.14)	t=1.38 (p=0.16)	1.7 (se=0.15)	1.2 (se=0.13)	t=2.24 (p=0.02)
Geometric mean	42.7	21.9		47.9	17.4	
% positives (Italian law)	41.2 (42/102)	36.2 (37/102)	McN=1.71 (p=0.19)	60.8 (62/102)	47.0 (48/102)	McN=10.32 (p=0.001)
Air-water syringes						
	22 °C			36 °C		
	T_0	T_1	statist. anal.	T_0	T_1	Statist. anal.
Logarithmic mean	1.8 (se=0.15)	1.4 (se=0.14)	t=2.11 (p=0.03)	1.7 (se=0.13)	1.2 (se=0.13)	t=2.55 (p=0.01)
Geometric mean	64.6	23.4		49.0	16.6	
% positives (Italian law)	48.9 (47/96)	31.6 (30/95)	McN=13.14 (p=0.0003)	63.5 (61/96)	46.3 (44/95)	McN=13.14 (p=0.0002)
Tap water						
	22°C			36°C		
	T_0			T_0		
Logarithmic mean	0.5 (se= 0.07)			0.7 (se= 0.10)		
Geometric mean	3.0			5.4		
% positives (Italian law)	4.4 (4/91)			29.3 (27/91)		

Table 4. Prevalence of *Legionella* spp and *P. aeruginosa* in samples from DUWs

<i>Legionella</i> spp	<i>P. aeruginosa</i>		Total n. (%)
	Negative n. (%)	Positive n. (%)	
Negative	47 (54.0)	11 (12.7)	58 (66.7)
Positive	28 (32.2)	1 (1.1)	29 (33.3)
Total	75 (86.2)	12 (13.8)	87 (100.0)

One-tailed Fisher's exact test $p=0.042$.

Table 4 shows the presence of *Legionella* spp. and *P. aeruginosa* isolated from 87 DUWs. The prevalence of *P. aeruginosa* was 13.8%, while the prevalence of *Legionella* spp. was 33.3%. Only one sample (1.1%) was positive both for *P. aeruginosa* and *Legionella* spp., while 47 (54.0%) were negative for both microorganisms (one-tailed Fisher's exact test, $p=0.04$).

As regards air contamination, IMA was almost four times higher at T_1 than at T_0 (Table 5), with statistically significant differences between the two sampling times ($p<0.0001$). Instead, the level of air contamination assessed by SAS did not change between T_0 and T_1 (from 104.7 CFU/m³ mean value at T_0 to 107.2 CFU/m³ at T_1 , $p=0.39$) (Table 6). The level of MA on the countertops and switches of the dental units increased (Table 7), with no significant differences between T_0 and T_1 .

Table 5. Mean levels of air contamination assessed by IMA (TVC at 36°C, CFU/plate), prevalence of samples with bacterial levels above the threshold level (25 CFU/plate)

	T_0	T_1	Statistical analysis
Logarithmic mean	0.8 (SE=0.11)	1.4 (SE=0.07)	$t=4.48$ ($p<0.0001$)
Geometric mean	6.5	23.4	
% positives	12.5 (4/32)	56.2 (18/32)	McN=12.07 ($p=0.0005$)

Table 6. Mean levels of air contamination assessed by SAS (TVC at 36°C, CFU/m³), prevalence of samples with bacterial levels above the threshold level (180 CFU/m³)

	T_0	T_1	Statistical analysis
Logarithmic mean	2.0 (SE=0.05)	2.0 (SE=0.07)	$t=0.11$ ($p=0.91$)
Geometric mean	104.7	107.2	
% positives	39.1 (18/46)	34.8 (16/46)	McN=0.75 ($p=0.39$)

Table 7. Mean levels of microbial accumulation (TVC at 36°C, CFU/cm²) of operative surfaces (tray, buttons), prevalence of samples with levels above the threshold level (1 CFU/cm²)

	T ₀	Trays T ₁	Stat. anal.	T ₀	Buttons T ₁	Statistical analysis
Logarithmic mean	0.01 (SE=0.08)	0.12 (SE=0.08)	t=1.10 (p=0.27)	-0.15 (SE=0.09)	0.005 (SE=0.09)	t=1.23 (p=0.22)
Geometric mean	1.0	1.3		0.7	1.0	
% positives	51.4 (57/111)	54.1 (60/111)	McN=0.31 (p=0.58)	48.2 (53/110)	52.7 (57/110)	McN=1.8 (p=0.18)

Discussion

The aim of this study was to evaluate knowledge and behavior of dental personnel in relation to prevention of infectious diseases, in order to highlight at-risk situations for operators and patients, and to define appropriate educational programs. At the same time, the microbial contamination of air, water and surfaces of some work environments was analyzed. Participation in the study was high, with a responding percentage (78.9%) higher than that of other studies (4, 13, 18, 19).

Overall, knowledge about the diseases that are transmissible in dental care should be improved: the majority of subjects did not cite tuberculosis, herpes or influenza, and had inadequate information about viral hepatitis. Knowledge of infections did not always include those more easily transmitted (such as influenza), but probably did include those that are perceived as particularly severe (such as AIDS). Moreover, information about disinfectant compounds and toxic products should be more widespread. It has to be noted that a few dentists considered their knowledge level to be high, while the majority considered it to be sufficient.

About a third of subjects could not name correctly the disinfectants employed, and among the toxic products, amalgam was rated above glutaraldehyde and below compounds that are more toxic, such as chloroform or solvents for resins. The use of individual protection systems was widespread, but re-capping needles was still practiced by 44.1% of subjects, and hands were not always washed between patients. In comparison with previous studies, the use of individual protection systems seems to have improved (4, 13, 18, 19, 24). However, the number of operators who did not protect themselves properly was higher than that in other countries (Table 1). The majority of personnel were immunized against HBV, but this practice should be adopted by all operators, and seroconversion tests and other vaccinations should be also considered.

DUWSs were not always properly disinfected, and the filtration and demineralization procedures, which allow an increase in bacterial load, were frequent. Moreover, in 40% of the cases, more than one dental unit was in the same room, which allows cross-contamination

through aerosols, which is also promoted by the lack of high-speed aspirators for the reduction of sprays.

Considering that the taps were frequently manual, that cordless and speakerphones were insufficient, that autoclaves or chemiclaves were sometimes absent, and that sterilization checks through biological assay were insufficient, it is possible to conclude that microbial contamination of the environment and devices was not always properly controlled. Moreover, the protection of surfaces with polyethylene films was rarely performed and sterilization of heat-sensitive materials was not properly carried out by a lot of operators. This seems to correspond with other studies, which have demonstrated insufficient adherence to guidelines by Italian dentists (4, 21). It has to be noted, however, that the questionnaire could not distinguish between what they declared on the basis of their knowledge and what they really practice. However, the questionnaire may represent a good and economic instrument to verify the level of knowledge and awareness of infection risks, especially in repeated studies (24).

Some dental surgery environments in the eight cities involved in this study showed high levels of biocontamination. Water from oral rinsing cups and air–water syringes was already contaminated before work activity started, but the total microbial count never exceeded 500 CFU/mL (CDC 2003 threshold). The percentage of positive samples significantly decreased during the day ($p < 0.05$), especially in air–water syringes. Some authors [9, 22] have suggested that this may result from the presence of biofilms in DUWSs, as well as night-time stagnation, and in most cases, from the absence of adequate disinfection systems. Moreover, this seems to confirm that when water and air emission from syringes stops, a short depression sucks in external polluting particles [39].

Ineffective maintenance and disinfection of dental units probably caused *P. aeruginosa* colonization, as demonstrated by the percentage of positive water samples (13.8%). Moreover, *P. aeruginosa* can obscure the presence of *Legionella* spp. [39]. Thus, even if the total microbial count does not always represent a risk for patients and health care workers, the presence of an opportunistic pathogen like *P. aeruginosa* may be dangerous, especially when associated with others microorganisms with a predilection for water habitats (e.g. *Legionella* and *Aeromonas* spp.) [39]. The water contamination results obtained in this study provide a contribution to the wider European investigation [44], which did not include Italian data. TVC was similar to the lowest reported counts, while the percentage of samples positive for *Legionella* spp. and *P. aeruginosa* was higher.

As for air microbial contamination, a high percentage of samples exceeded the limits of 25 and 180 for IMA and CFU/m³, respectively, whereas their mean values were lower than the threshold. IMA values increased during work activity ($p < 0.0001$), as expected, while CFU/m³ values remained almost unchanged. Since an increase in air biological contamination caused by microbial dispersion from people and production of microbial aerosols is inevitable in dental practices, these results seem contradictory. A mutual relationship between the results obtained by active and passive sampling has been demonstrated in some studies [12, 17, 29, 33, 34, 35, 45]. Our study showed the need to promote further studies in this field.

As to surfaces, high MA was registered at the beginning of work activities and increased during the day, but not significantly. More than 50% of samples showed values above the threshold. This was probably caused by inadequate disinfection at the end of work activities and the absence of proper aspiration systems, which caused a night-time fall-out of airborne

particles. On the other hand, the contamination level does not exclusively depend on the number of patients and health operators, but also on failure to use films, blotting papers or trays to protect work surfaces on which instruments are placed during treatment, and which can easily be contaminated by aerosols, while the push-button panel shows contamination due to manipulation.

An exhaustive analysis of microorganisms in air and surfaces was not completed, because the aim of this study was to propose a monitoring method for obtaining quantitative data, such as indicators of environmental hygienic conditions, leaving aside for the moment, identification of specific pathogens and the study of particular situations such as epidemic events.

Conclusion

The information obtained from the questionnaire survey of this sample of public Italian dentists revealed gaps in the prevention of infectious diseases, and demonstrated the need for educational programs for all the dental operators to improve their health behavior in terms of respecting the hygienic rules for risk management. The lack of knowledge may contribute to environmental contamination, which is particularly important, as various pathogens may be transmitted from the environment to patients. Dental care is still a risk factor for several infections, especially in immunocompromised subjects [31]. Some authors have insisted on the importance of individual protection systems and of frequent disinfection procedures in order to reduce the infection risk associated with dental aerosols, although the efficacy of these products varies over time [8, 40].

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DropBooks

Chapter 8

Treating Children with Cleft Lip and Palate: Special Needs and Attention Required During Dental Care

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Abstract

Cleft lip and palate are relatively common congenital malformations. Individuals with this anomaly present characteristic growth and development of the face and stomatognathic system and have some special needs as to the dental care. However, when properly informed and trained, any dental practitioner may deliver high-quality dental care to these patients. Several studies around the world have demonstrated higher caries prevalence among children and adults with cleft lip and palate compared to individuals without clefts. With regard to the children, several factors may contribute for the increased caries risk, including the irregular positioning of teeth; presence of lip fibrosis, which impairs the access for toothbrushing; and the dietary needs of infants, which are breastfed less frequently and for shorter periods, thus having earlier contact with sugar and acidic juices in the baby bottle. In addition to these aspects, many parents may be overindulgent and allow them to eat candies more frequently as an attempt to compensate for the presence of the cleft. The anterior region presents a shallow and fibrotic buccal sulcus, which may complicate the injection of local anesthesia. Thus, topical anesthetic should be applied before the injection, followed by slow and careful injection on the buccal region. The papilla may be penetrated with the anesthetic needle for achievement of initial anesthesia of the palatal region before direct injection in the palate, to avoid pain and discomfort. Also, when treating teeth at the cleft area, it may be necessary to anesthetize both segments anterior and posterior to the alveolar cleft, because these

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regions present independent innervation due to the presence of the cleft. Tooth extraction and restorative procedures may be performed as usual. In patients with unoperated cleft palate, care is required to avoid aspiration of fragments of teeth and restorative material. Whenever possible, the rubber dam should be used as a protective measure. Knowledge on these different aspects allows dental professionals to provide adequate dental care to these patients, providing favorable conditions to enhance their oral hygiene, esthetics and function and giving an important collaboration for their full rehabilitation.

Introduction

The craniofacial malformations constitute a public health problem, often neglected due to lack of knowledge and adequate information on the pathology and its consequences. Among the alterations affecting the cranium and face, cleft lip and/or palate are the most common because their formation occurs early in the intrauterine life, during the gestational and embryonic (4th to 8th weeks) periods and onset of the fetal period, in which highly complex and coordinated events involve proliferations, inductions, migrations and cell differentiations. These periods are highly sensitive to alterations in the internal or external environment.

The face is formed by the frontonasal embryonic prominences, which are originated from the neural plate, and by the maxillary and mandibular prominences, originated from the first branchial arch. Migration of the neural crest cells gives rise to the ectomesenchyme, which acts in the elimination of grooves between the processes and originates the tissues involved in the face formation: skeletal, neural, dental (except for enamel) and connective tissues. The frontonasal prominence originates the medial and lateral nasal prominences that surround the olfactory placodes, of ectodermal origin; the union of the formers gives rise to the intermaxillary segment. Part of this structure is joined to the maxillary prominences and constitutes the middle facial third. The alignment of the mandibular prominences gives rise to the lower facial third. The primary palate or premaxilla originates the intermaxillary segment; together with the secondary palate, whose palatal shelves belong to the maxillary prominences, they give rise to the palate, which separates the oral and nasal cavities. This process occurs between the 6th and 12th weeks of intrauterine life. Oral clefts may occur when there is any interference during this process of embryonic development [Ten Cate and Nanci, 2003].

The early development of the face is controlled by interactions between the epithelium and mesenchyme. Current studies have been addressing the influence of genes (MSX1, IRF6, and others), transcription factors (TGF α and TGF β), growth factors and bone morphogenetic proteins, both on the complexity of face formation and on the occurrence of clefts [Lidral et al., 1998; Van den Boogaard, 2000; Kondo et al., 2002].

The clefts may affect the lip, the palate, or both. They may also occur as an isolated disorder, combined with other malformations, or as part of syndromes.

In general, the occurrence of cleft lip and/or palate presents a mean prevalence of 1 to each 1,000 livebirths. Since this group is highly complex and diverse, the reported prevalence is variable due to divergences and failures in the records around the world. However, the reports indicate ethnic differences in the prevalence, affecting, in decreasing order, the American natives (1:270), individuals of Asian descent (1:370), Caucasoids (1:588), and

subjects of African descent (1:2500) [Vanderas, 1987; Tolarova and Cervenka, 1998; Watson, 2005]. Cleft lip with or without cleft palate is twice more frequent among males, while isolated cleft palate is more frequent among females [Watson 2005].

Despite the advances in world researches, the causes of oral clefts are not fully understood. It is believed that non-syndromic cleft lip and/or palate has a multifactorial etiology, involving genetic and environmental factors [Murray 1995]. Studies conducted on families and twins have supported the genetic predisposition in these cases, because the facial development is complex and partly determined by genetic aspects, i.e. the molecular signalizations involved in cell adhesion, production of intercellular matrix, programmed cell death, cell transformation and migration of neural crest cells may determine the genetic component in the etiology of clefts. These genes may contribute to the genetic susceptibility, interacting with each other and with the environmental factors.

Some environmental aspects are reported as teratogens in the etiology of clefts, such as phenytoine, methotrexate and sodium valproate. The phenytoine was confirmed as a teratogen because it interferes with the growth of lateral nasal prominences, leading to the occurrence of cleft lip [Strickler et al., 1985]. Moreover, alcohol [Munger et al., 1996] and tobacco use [Little et al., 2004] have been constantly cited and discussed in the literature as agents that may increase the individual susceptibility to clefts. The folic acid seems to play a protective role in the occurrence of clefts [Czeizel, 1998].

Non-syndromic clefts are the most commonly observed. Studies suggest that nearly 50% of cases of cleft palate and 70% of cases of cleft lip and palate are non-syndromic, thus are not associated with any other physical or developmental abnormality [Milerad et al., 1997; Hagberg et al., 1998; Saal, 1998; Tolarova and Cervenka, 1998; Stoll et al., 2000].

When present, the malformations of upper and lower limbs or of the vertebral column are anomalies most commonly associated with cleft lip and/or palate, accounting for 33% of all defects, followed by malformations of the cardiovascular system (24%). The literature has reported up to 400 syndromes with oral clefts among their characteristics, with Mendelian and non-Mendelian inheritance, chromosomal alterations, or of teratogenic origin. The most common syndromes are the van der Woude, Stickler, Treacher Collins, velocardiofacial and EEC syndromes and the Robin sequence [Lees, 2005].

The risk of recurrence of oral clefts has been a matter of concern for both professionals and families. This risk differs between syndromic and non-syndromic clefting. In the latter, the recurrence is based on empirical data observed on different families and populations. The risk predictors are the number of affected relatives and the severity of the lesion, i.e. the greater these aspects, the higher will be the risk of recurrence [Lees, 2005].

The cleft lip and/or palate presents variable extent, from a small notch on the lip up to complete division of the maxilla, involving the lip and palate. A classification system aiming at their description has been long studied, in order to enhance the communication between investigators; however, no classification has been universally accepted so far. Different manners have been used to organize the clefts, either by symbolic schemes or considering the embryonic and morphological aspects, which is the most frequently observed and accepted. Most reports in the literature group the clefts in a simplified manner, according to the structures affected, e.g. cleft lip (CL), cleft palate (FP), and cleft lip and palate (CLP). Abbreviations are also used to indicate the complete (C) and incomplete (I) clefts and

unilateral (U) and bilateral (B) clefts. This classification is simple yet not adequate, especially when further details on the pathology are required. Thus, the clefts will be herein described indicating the anatomical structures affected (Figures 1 to 11).

The different types of clefts affect the face anatomy in different manners; consequently, they give rise to peculiar functional, orthodontic and dental disorders and thus require different treatment protocols. Clefts are not a single disorder; rather, they should be studied and understood considering their diversity.

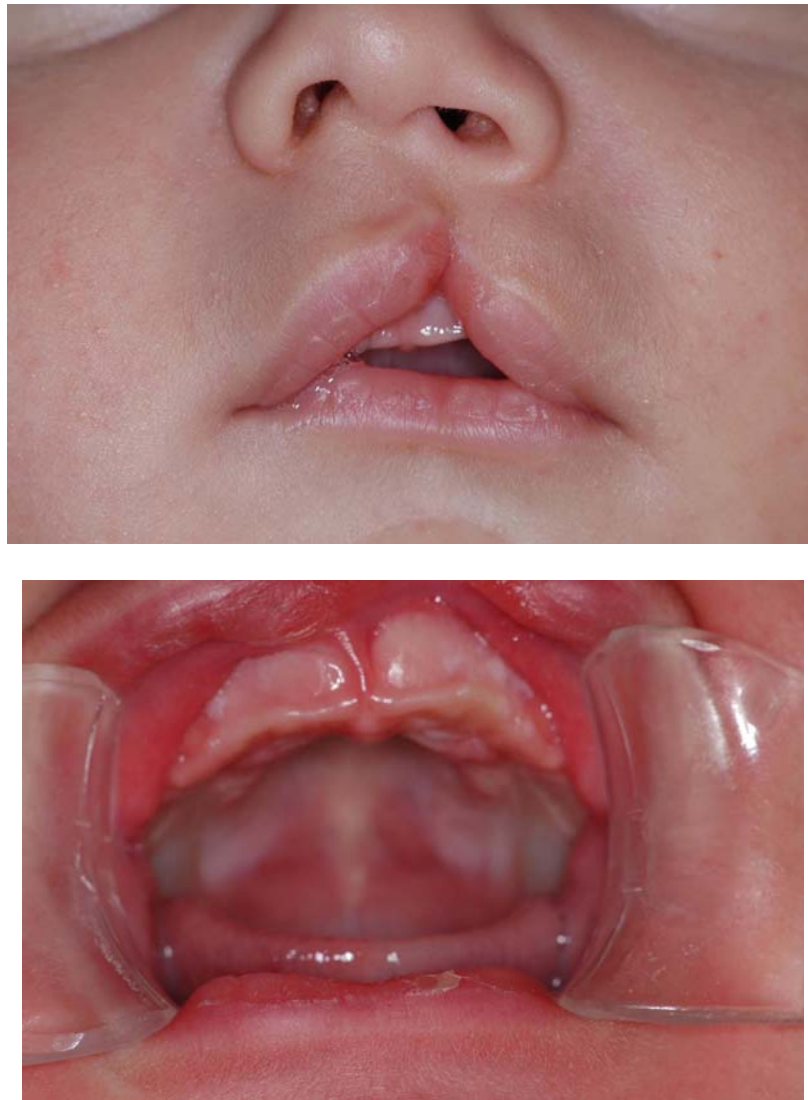


Figure 1. A) Incomplete unilateral left cleft lip. B) The alveolar ridge is intact.



Figure 2. A) Complete unilateral right cleft lip. B) The alveolar ridge is disrupted up to the nasal floor.



Figure 3. (Continued).



Figure 3. A) Incomplete bilateral cleft lip. B) The alveolar ridge is intact at both sides.



Figure 4. A) Complete bilateral cleft lip. B) The alveolar ridge is completely disrupted up to the nasal floor at both sides.



Figure 5. A) Incomplete median cleft lip. B) There is partial involvement of the alveolar ridge.



Figure 6. (Continued).



Figure 6. A) Complete median cleft lip. B) Absence of columella, prolabium and premaxilla.



Figure 7. A) Complete unilateral left cleft lip and palate. B) Complete disruption of the lip, alveolus and palate.

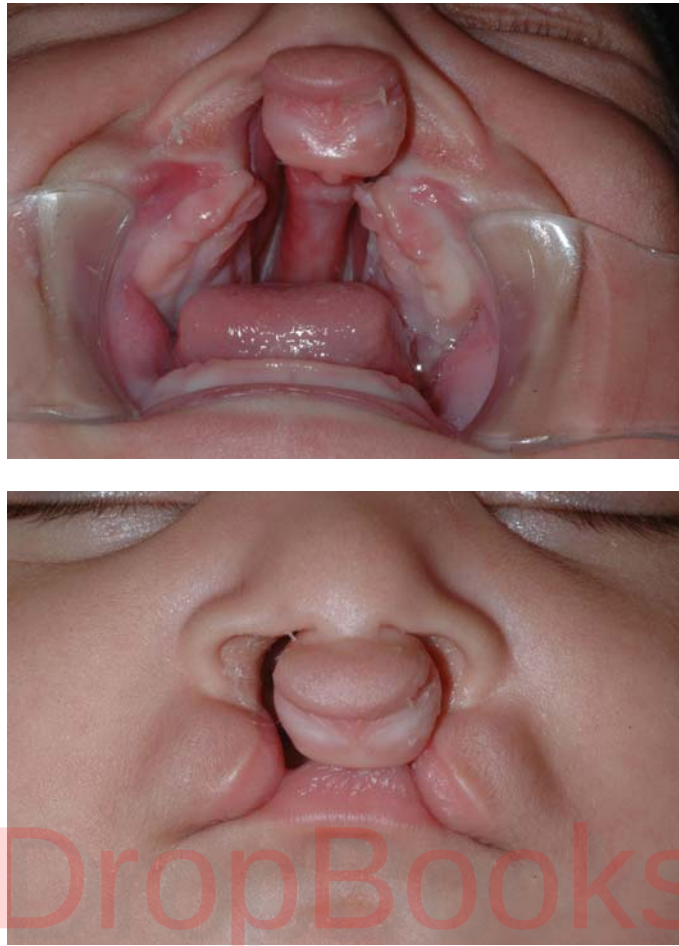


Figure 8. A) Complete bilateral cleft lip and palate. B) Complete disruption of the lip, alveolus and palate bilaterally, anteriorly observing the premaxilla.



Figure 9. (Continued).



Figure 9. A) Complete median cleft. B) Absence of midline structures of the lip, as well as of the nasal septum.



Figure 10. Incomplete cleft palate, affecting the soft palate.



Figure 11. Complete cleft palate. The cleft affected from the uvula to the incisive foramen.

Dental Aspects in the Management of Infants with Cleft Lip and Palate

Children with cleft lip and palate present peculiar dental characteristics since birth. Ideally, any child should have the first contact with the dental professional during the first year of life. This approach has revealed beneficial effects on the oral health of children, especially concerning the prevention of dental caries. However, for this specific population group, the main concern of families during early childhood is the accomplishment of primary repair surgeries, which follows specific protocols at each cleft center. Usually, lip repair is performed at 3 to 6 months of age, and palate repair is accomplished at the age of 1 year.

As described, there are several types of clefts that affect different structures, consequently causing different extents of dental disorders.

This section of the chapter describes the main aspects of infants with cleft lip and palate and the dental management at this stage.

Breastfeeding

This aspect raises several doubts when dealing with infants with clefts. The mothers and even the health professionals do not believe that the child may be breastfed, as evidenced by studies demonstrating that a low percentage of children with clefts receive breastfeeding. However, breastfeeding should always be encouraged and may be possible depending on the effort and motivation of the mother, who should receive adequate counseling [Young et al., 2001].

For infants with isolated cleft lip, the greatest challenge for breastfeeding is the grasping and sealing of the nipple for suction. In this case, the mother may be guided to promote the sealing herself with the breast (Figure 12). With regard to cleft lip and palate and isolated cleft palate, the infant is unable to establish the necessary intraoral negative pressure when positioning the tongue between the nipple and the palate, due to the presence of the palatal cleft. In these cases, the possibility of breastfeeding will depend on the mother motivation for the attempts and the infant adaptation to this situation. Despite these difficulties, breastfeeding should always be attempted and encouraged by the health professionals involved in the care to newborns, because it involves important emotional and physiological aspects for both the mother and the infant [Clarren et al., 1987].

If breastfeeding is impossible, the infant must be fed using a baby bottle. Rubber bottle nipples should be used, because silicone nipples are more rigid and may cause ulcerative lesions on the nasal septum exposed by the cleft palate (Figure 13).



Figure 12. Adequate positioning for breastfeeding.



Figure 13. Ulcerative lesion caused by the bottle nipple.

The nipple should have orthodontic shape and a 0.8- to 1-mm orifice to allow the milk to flow in drops. This way, the infant will have to suck strongly and will exercise the orofacial musculature.

Other options for infant feeding that avoid the contact with the bottle nipple are the use of disposable plastic glasses and spoons. In both cases, the infant should be fed offering small quantities.



Figure 14. Half-seated position of the infant for feeding.

In any case, the infant should be always kept half-seated during feeding (Figure 14) to reduce the risk of choking and milk reflux to the auditory tube, which at this age presents horizontal positioning aligned with the soft palate. The auditory tube dysfunction and the communication between the oral and nasal cavities caused by the cleft predispose these infants to higher risk of recurrent ear infections, which may damage the hearing function in the future [Dalben et al., 2002].

Another important aspect from a dental standpoint concerns the utilization of the baby bottle and the early introduction of sugar in the diet, which may favor and increase the occurrence of caries. Ideally, if a baby bottle is used to feed the infant, sugar should not be added to the formula or milk to delay the first contact with sugar. This represents a healthy dietary habit from a nutritional standpoint and is also beneficial for the prevention of caries [Dalben et al., 2003].

Common Oral Characteristics in Early Childhood

The most common tooth abnormalities in infants with clefts involve the tooth eruption and are related with the extent of the defect. The natal or neonatal teeth are the most prevalent at this age range, affecting 2% of children with unilateral cleft lip and palate and 11% of children with bilateral cleft lip and palate [Almeida and Gomide, 1996]. These teeth are usually located at the cleft area and most present mobility due to the poor bone

implantation, since in general no root formation occurs. These teeth should be extracted due to the high risk of aspiration of these teeth, considering the communication between the oral and nasal cavities in the presence of an unrepaired cleft (Figure 15).



Figure 15. Neonatal tooth in infant with complete bilateral cleft.

The gingival cysts of the newborn are also commonly observed in children with cleft lip and palate, similarly to infants without clefts. They present a nodular aspect with yellow-whitish color and may occur on the alveolar ridge, mucosa, or on the palate (Figures 16 and 17). No specific treatment is required for these cysts rather than follow-up until spontaneous regression of the lesion.

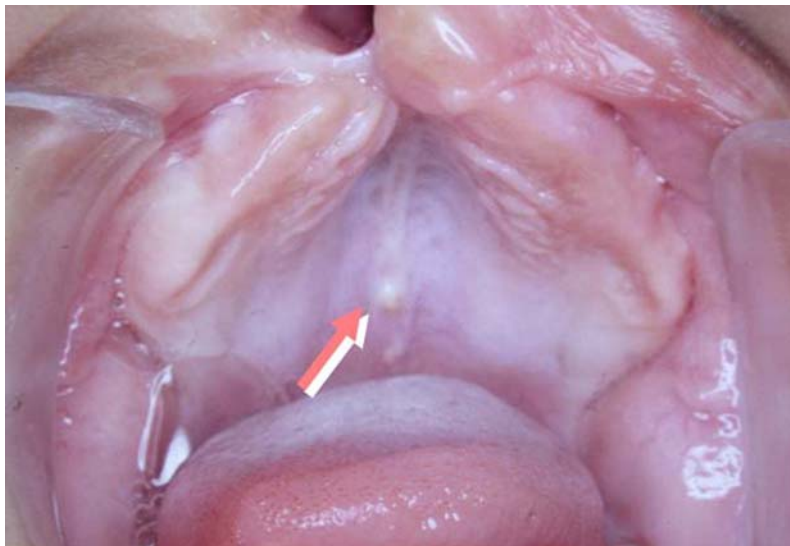


Figure 16. Gingival cyst of the newborn located on the palatal raphe.

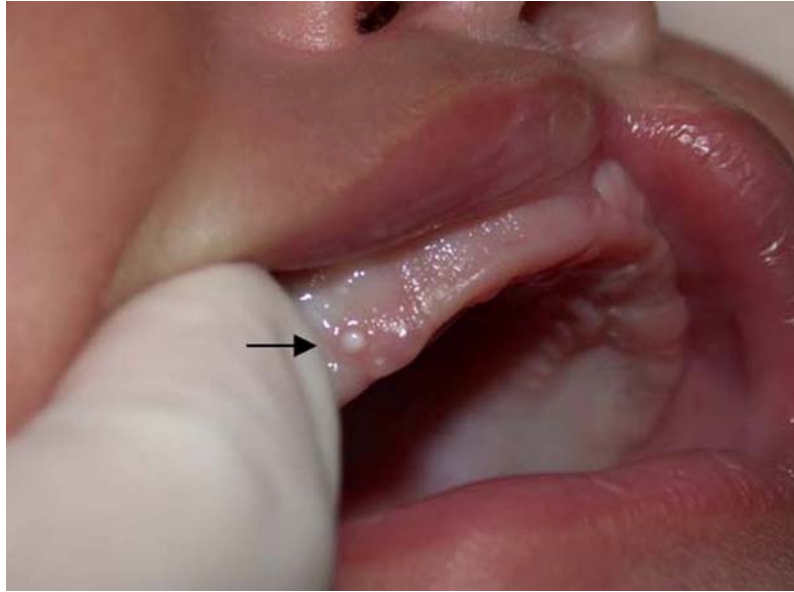


Figure 17. Gingival cyst of the newborn located on the alveolar ridge.

Dental Treatment

The adequate oral health status is fundamental for the accomplishment of any rehabilitative plastic surgery in children with clefts. The presence of carious lesions precludes the surgical procedure, due to potential risk of contamination of the surgical site by the microbiota present in the lesion.

The caries prevalence in children with clefts is high compared to the rates reported on children without clefts. These results may be partly explained by the difficulties faced by parents for the accomplishment of oral hygiene, due to the occurrence of several tooth abnormalities that favor the plaque accumulation and occurrence of dental caries. Conversely, the parents also often report that they fear to cause any injury to the operated site during toothbrushing [Neves, 2002]. Within this context, the work of dental professionals is fundamental to encourage and provide information to the parents for an adequate dental follow-up.

The dental care to infants with clefts involves two stages. The first comprises counseling, during which the professional provides information to the parents or caretakers concerning the diet, frequency of feeding, type of toothbrush and utilization or not of dentifrices according to the age, as well as the adequate quantity of dentifrice, emphasizing the risk of swallowing. During this counseling, the child has a first indirect contact with the professional and the environment, which is positive from the standpoint of pediatric dental management.

The second stage involves the clinical procedure, in which the child is placed on a dental chair for infants and the professional manages the child in accordance with his or her age range, performs oral hygiene and clinical examination involving inspection of the soft and hard tissues. Based on this examination, the treatment planning is defined, which is divided in preventive and restorative treatments [Costa et al., 2002].

Preventive Treatment

Before tooth eruption, the preventive treatment comprises cleaning of the oral cavity with gauze, a cloth or cotton swabs moistened with saline or filtered water. The hygiene should be performed on all regions of the mouth, including the alveolar ridges, oral mucosa, inner part of the cleft and the tongue (Figure 18). The parents should be instructed to examine the child's mouth frequently and search for professional advice if any abnormality is observed.

After eruption of the first tooth, the preventive procedure should be performed using a toothbrush (Figure 19) or performing professional prophylaxis, always reinforcing the utilization of fluoride dentifrice only after 1 year of age and in a quantity corresponding to 1/4 of a rice seed. The toothbrush should have extra soft bristles, small and rounded head and a good handle to be used by an adult. If the child presents teeth with enamel hypoplasia, which is very common in patients with cleft lip and palate, these teeth should receive application of fluoride varnish or even preventive restorations by filling the defect with glass ionomer cement.



Figure 18. Demonstration of oral hygiene in edentulous infant.

Restorative Treatment

When the infant requires restorative treatment, it is usually performed under physical restraint, with the help and consent from the parents or caretakers. Negative behavior is expected after 1 year of age, and the child commonly cries to relieve the stresses related to the environment, procedures and the physical restraint itself. The restraint is necessary to protect the child (Figure 20).

The most common restorative treatments in early childhood are described below.



Figure 19. Demonstration of toothbrushing in infant with teeth.



Figure 20. Position of the mother for physical restraint during attendance of the infant.

Extraction of Natal/Neonatal Teeth

As previously described, when the infant presents this alteration, extraction of these teeth is indicated in most cases because the tooth usually presents mobility and poses the risk of aspiration. The procedure is performed only with application of topical anesthesia after careful drying of the mucosa, since the tooth does not present bone implantation. The extraction may be performed with a spatula n. 7 and hemostasis is achieved by compressing the site with sterile gauze, without need of suture (Figures 21 to 23).



Figure 21. Neonatal tooth in infant with complete unilateral cleft.



Figure 22. Protection of the upper airway with gauze before extraction.



Figure 23. Macroscopic characteristic of the extracted neonatal tooth.

Carious Lesions with Active White Spots

Infants with active white spots should receive treatment with fluoride varnish for remineralization of these lesions. This is the material of choice up to the age of 3 years, because the varnish presents high adherence to the enamel and there is no risk of swallowing. Obviously, in addition to the restorative treatment, the parents should be encouraged to change the inadequate habits and should receive information on how to perform the daily oral hygiene adequately.

Before application of fluoride varnish on the teeth affected by these lesions, the teeth should be cleaned by prophylaxis or toothbrushing, the teeth must be air-dried and the site should be isolated with cotton rolls [Correa, 1998].

This procedure should be preferably performed after the meals, since the child should not eat hard foods for a minimum period of 2 hours and brush the teeth for a minimum period of 12 hours after the procedure. The parents should be informed that the teeth will exhibit a yellowish aspect until the varnish is spontaneously released from the tooth surface (Figure 24).

Incipient Carious Lesions

In the presence of incipient carious lesions in infants, the atraumatic restorative treatment has been successfully indicated (ART). This type of treatment is indicated only for incipient

lesions; effective removal of the decayed tissue is necessary because the infants are often submitted to plastic surgeries for cleft repair after the dental treatment.



Figure 24. Application of fluoride varnish on anterior teeth presenting active white spots.

The technique comprises removal of the decayed tissue using excavators. There is no need of local anesthesia, because the incipient lesions are usually shallow (Figures 25 to 29).



Figure 25. Incipient carious lesion indicated for accomplishment of atraumatic restorative treatment.



Figure 26. Removal of decayed tissue using an excavator.



Figure 27. Application of primer for restoration with glass ionomer cement.



Figure 28. Restoration with light-cured glass ionomer cement.



Figure 29. Final aspect of the restoration after application of the finishing gloss.

Extensive Carious Lesions

In cases with extensive carious lesions, conventional dental treatment must be performed under local anesthesia and preferably using a rubber dam (Figure 30). It should be highlighted that children up to 3 years of age present low weight, proportional to their age; thus, the professional should carefully observe the safe quantity of local anesthetics to be applied when treating infants in the early childhood.



Figure 30. Conventional treatment performed in infant under physical restraint.

Mixed and Deciduous Dentitions: Characteristics, Particularities and Alterations

From an embryonic standpoint, the formation of tooth buds and the occurrence of cleft lip and/or palate present a very close relationship, both concerning the period of formation and the anatomical position. Around the eighth week of intrauterine life, the leveling and union between the frontonasal, maxillary and mandibular prominences are complete and specific odontogenic growth centers are evident for the deciduous central incisors and the respective permanent incisors.

Clinically, tooth abnormalities are frequently observed in children with cleft lip and palate. The occurrence of these alterations is directly related to the degree of anatomical involvement of the cleft, i.e. the greater the extent of the defect and the number of structures involved, the higher will be the possibility and severity of its occurrence. Several phenomena, including delayed tooth eruption, structural and morphological tooth abnormalities and variations in tooth number and positioning are observed, mainly close to the alveolar ridge

area affected by the cleft (region of the lateral incisor) [Suzuki et al., 1992; Tsai et al., 1998; Maciel et al. 2005; Stahl et al., 2006; Tortora et al., 2008].

Even though these alterations are considered as sequelae of the cleft, their precise etiology is still unknown. The investigations have indicated the following assumptions:

- Influence of the same pathological processes causing the cleft [Jordan et al., 1966; Malanckzuk et al., 1999], also considering the presence of similar genetic components for the occurrence of these alterations and clefting [Slayton et al., 2003];
- Influence of the anatomical alteration of the alveolar ridge, which may result in an insufficient quantity of mesenchymal mass to allow the normal tooth development [Vichi and Franchi, 1995; Tsai et al., 1998; Ribeiro et al 2003];
- Influence of the surgical procedures performed for cleft repair, which may cause local metabolic and nutritional disorders (reduced blood supply and presence of scar tissue) [Dixon and Ranta, 1986].

Tooth Eruption

Tooth eruption in children with cleft lip and palate may be affected by the anatomical malformation and/or a delay in tooth development [Ranta, 1986].

Evaluation of the chronology of eruption of deciduous teeth in children with complete unilateral cleft lip and palate revealed that teeth at the cleft side exhibit more delayed eruption compared to teeth at the non-cleft side, with statistically significant difference only for the maxillary lateral incisor and canine (Figure 31) and for the mandibular lateral incisor [Duque et al., 2004]. The association between the cleft side and the delayed eruption observed in both arches might be explained by the most superior and posterior positioning of the cleft segment, which would be exposed to lower masticatory stress, thus causing a delay in tooth eruption due to functional factors, both in the maxilla and the mandible [Kramer et al., 1993].



Figure 31. Delayed eruption of deciduous lateral incisor adjacent to the cleft in patient with complete unilateral cleft lip and palate.

A single alteration was observed in the sequence of eruption, related to the deciduous maxillary lateral incisor at the cleft side, which was the last tooth to erupt in the oral cavity [Duque et al., 2004]. According to Kramer et al. (1989), who also observed this phenomenon, this might be explained by an apical displacement of the tooth bud of the lateral incisor in the presence of complete cleft lip and palate, which affects the nasal floor and alveolar ridge, increasing the length of the eruption pathway.

The knowledge on the chronological pattern and sequence of eruption of deciduous teeth in children with cleft lip and palate allows the dental professionals to provide information to the parents on the possibility of delayed eruption, especially of the maxillary lateral incisor adjacent to the cleft, without the need to achieve radiographies that might expose the patient to unnecessary risks to his or her health, at an early age.

The pattern of eruption of permanent teeth was also evaluated in patients with complete unilateral cleft lip and palate, revealing that the maxillary lateral incisor and canine adjacent to the cleft also exhibited significantly delayed eruption compared to the contralateral teeth at the non-cleft side. This characteristic was assigned to a multifactorial etiology related to extrinsic and intrinsic factors that participate in the tooth development of patients with clefts, such as: lack of supporting alveolar bone, lack of space in the maxilla, nutritional factors, surgical procedures (fibrotic scars), genetic factors and loss of occlusal contact at the cleft side, leading to an irregular distribution of occlusal forces at the cleft segment [Carrara et al., 2004].

Ectopic Tooth Eruption

Ectopic Eruption of the Permanent Maxillary First Molar

Patients with cleft lip and palate present high occurrence of ectopic eruption of the permanent maxillary first molar, with prevalence of 20.6% in cleft palate [Silva Filho et al., 1993], 19.6% in complete unilateral cleft lip and palate [Silva Filho et al., 1990] and 20% in cleft lip and alveolus [Silva Filho et al., 1996], compared to 2 to 6% observed in patients without clefts. The high prevalence of this disorder in the population with clefts is not fully understood. Several etiologic factors have been mentioned in the literature, including the negative influence from the reparative surgery on the maxillofacial growth. Another hypothesis is the reduced anteroposterior maxillary length in patients with cleft involving the palate. The maxilla presents retropositioning in relation to the cranial base, with reduction of sagittal length. However, since these maxillary characteristics are not observed in patients with cleft lip and alveolus, they may not be considered to explain the high prevalence of this alteration in this group of patients. Thus, Bjerklin et al. [1993] mentioned that, in addition to the surgical and anatomical aspects, the important role played by genetic factors in its etiology should be considered.

When present, most cases of ectopic eruption (nearly 70%) are reversible and do not require any type of treatment (Figure 32). Only 30% of cases present irreversible ectopic eruption, requiring extraction of the adjacent deciduous second molar and orthodontic mechanotherapy for space recovery at this region.

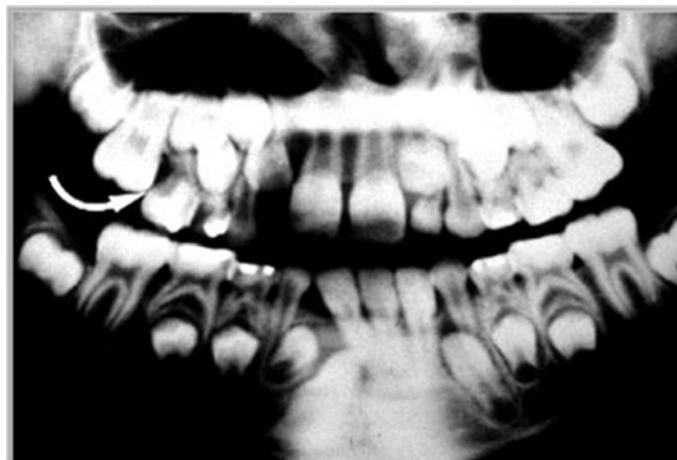


Figure 32. Reversible ectopic eruption of permanent maxillary right first molar.



Figure 33. A) Radiographic aspect of tooth (permanent central incisor) whose crown is directed to the nasal cavity. B) Clinical aspect of extraction of the intranasal tooth.

Intranasal Tooth Eruption

Teeth erupting in the nasal cavity may also be observed in patients with cleft lip and palate. A study conducted at the Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo evaluating the records of 1,495 patients with complete unilateral and bilateral cleft lip and palate revealed prevalence of 0.41% and 0.61%, respectively. The probable etiologic factors include alterations in the development and leveling of facial prominences or the influence of reparative surgical procedures [Medeiros et al., 2000]. The diagnosis of intranasal tooth is performed by radiographic examination, after clinical complaint of frequent rhinorrhea and malodor in one nostril. The patient may also be referred by an otolaryngologist, who may observe the tooth in the nasal cavity during clinical examination. The treatment comprises extraction of the tooth erupted in the nasal cavity, even if the tooth is permanent or supernumerary, which is usually performed in an operating room under general anesthesia (Figures 33a and 33b).

Tooth Abnormalities of Shape, Number and Position

Investigations conducted on patients with different types of unilateral clefts revealed that the deciduous maxillary lateral incisor exhibits normal shape in most individuals (97.2% for isolated cleft lip, 89.9% for cleft lip and alveolus, and 82.7% for complete cleft lip and palate) [Suzuki et al., 1992]. However, the study of Gomide (1996) evaluating only the deciduous dentition of children with cleft lip with or without involvement of the alveolar ridge demonstrated occurrence of 15% of T-shaped or X-shaped lateral incisors (Figure 34).

In the permanent dentition of patients with unilateral clefts, the lateral incisor adjacent to the cleft exhibited abnormality of shape (peg-shaped aspect) in 33.3% of cases with isolated cleft lip (Figure 35), 60% of individuals with cleft lip and alveolus, and 35.3% of patients with complete unilateral cleft lip and palate [Suzuki et al., 1992].



Figure 34. X-shaped supernumerary tooth in patient with cleft lip without involvement of the alveolar ridge.



Figure 35. Peg-shaped permanent lateral incisor in patient with cleft lip without involvement of the alveolar ridge.

Ribeiro et al. (2003) analyzed only patients with complete unilateral cleft lip and palate and observed that, when present, nearly all permanent maxillary lateral incisors were peg-shaped (92.2%), while Stahl et al. (2006) found prevalence of microdontia of the lateral incisor in 54.4% of cases for complete unilateral clefts and 52.6% for complete bilateral clefts. The lateral incisor is frequently present in individuals with clefts affecting the primary palate, while individuals with clefts affecting the primary and secondary palates most commonly present agenesis of this tooth [Kim and Baek, 2006].

In unilateral clefts, the deciduous lateral incisor adjacent to the cleft is missing in 7.2% of cases of cleft lip and alveolus and in 15.2% of patients with complete cleft lip and palate. When present, the deciduous lateral incisor is predominantly located distally to the cleft (83.2 to 91.3%) (Figure 36). In the permanent dentition, the lateral incisor adjacent to the cleft is missing in 11.1% of cases with isolated cleft lip, 36.3% of patients with cleft lip and alveolus, and 56.9% of individuals with complete cleft lip and palate. When present, they are also mainly located distally to the alveolar cleft [Suzuki et al., 1992] (Figure 37).



Figure 36. Deciduous lateral incisor positioned distally to the alveolar cleft in patient with complete unilateral cleft lip and palate.

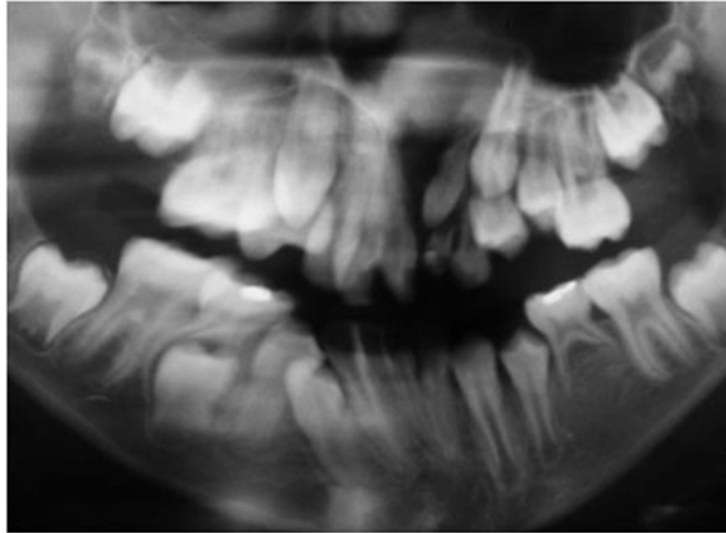


Figure 37. Panoramic radiographic revealing presence of peg-shaped permanent lateral incisor distally to the cleft in patient with complete unilateral cleft lip and palate.

Patients with cleft lip without involvement of the alveolar ridge tend to present permanent lateral incisors with normal shape (55.6%), while individuals with cleft lip and alveolus exhibit higher frequency of peg-shaped lateral incisors (60%) and patients with complete cleft lip and palate tend to present agenesis of the lateral incisor (56.9%) [Suzuki et al., 1992]. Several studies confirmed the high occurrence of agenesis of the permanent lateral incisor adjacent to the cleft in the presence of complete cleft lip and palate, both for unilateral clefts, ranging from 48.8 to 56.9% (Figure 38) [Suzuki et al., 1992; Tsai et al., 1998; Ribeiro et al., 2003; Kim and Baek, 2006; Stahl et al., 2006; Tortora et al., 2008], and for bilateral clefts, ranging from 43.3% to 52.6% (Figure 39) [Suzuki et al., 1992; Stahl et al., 2006; Tortora et al., 2008].

In individuals with complete bilateral cleft lip and palate, the deciduous lateral incisors are present bilaterally in 70.9% of cases, are usually positioned distally to the cleft (80%) and most exhibit normal shape (Figure 40).

Concerning the permanent incisors, there is high occurrence of bilateral agenesis of the lateral incisor (43.3%); however, when present, they are also frequently positioned distally to the cleft [Suzuki et al., 1992]. With regard to the isolated bilateral cleft lip, there is high frequency of supernumerary teeth (46.6% for females and 29.2% for males), compared to high prevalence of tooth agenesis (31.6%) in the presence of cleft lip and alveolus [Silva et al., 2008].

The occurrence of supernumerary teeth is more common in the deciduous dentition and in less extensive clefts, e.g. isolated cleft lip or with mild involvement of the alveolar ridge, while tooth agenesis is more frequent in the permanent dentition and in complete cleft lip and palate [Tsai, 1998]. Patients with unilateral cleft lip present high prevalence of supernumerary teeth in the deciduous dentition (Figures 41a and 41b).



Figure 38. Panoramic radiographic exhibiting agenesis of permanent lateral incisor adjacent to the cleft in patient with complete unilateral cleft lip and palate.



Figure 39. Panoramic radiographic demonstrating bilateral agenesis of permanent lateral incisor in patient with complete bilateral cleft lip and palate.



Figure 40. Presence of deciduous lateral incisors bilaterally, distally positioned in relation to the alveolar cleft, in patient with complete bilateral cleft lip and palate.



Figure 41. A) Extraoral aspect of patient with operated cleft lip. B) Intraoral aspect of patient with isolated cleft lip with supernumerary deciduous tooth.

Conversely, several studies demonstrated low prevalence of supernumerary teeth in the permanent dentition in patients with complete cleft lip and palate, ranging from 0.7% to 7.3% for unilateral clefts [Suzuki et al., 1992; Tsai, 1998; Ribeiro et al., 2003; Kim and Baek, 2006; Tortora et al., 2008] and 5% for bilateral clefts [Tortora et al., 2008].

The prevalence of hypodontia (tooth agenesis) outside the cleft area in this group of patients is also significantly high compared to individuals without clefts (Ranta, 1986; Jiroutova and Mullerova, 1994; Slayton et al., 2003; Letra et al., 2008). Particularly, the tooth most affected by hypodontia outside the cleft area is the maxillary second premolar, with percentages ranging from 24.1% to 36.4% [Tsai et al., 1998; Eerens et al., 2001; Ribeiro et al., 2003; Letra et al., 2008; Menezes and Vieira, 2008] considering the different types of cleft.

Slayton et al. (2003) observed positive association between patients with cleft lip or cleft lip and palate presenting hypodontia outside the cleft area (compared to controls without clefts) for both the muscle segment homeo Box homolog 1 (MSX1) and the transforming growth factor beta 3 (TGFB3). However, it was not possible to determine if this association was specifically related with the combination of cleft and hypodontia or if it occurred mainly due to the phenotype of the cleft.

More recently, Letra et al. (2008) confirmed that the premolars were the teeth most commonly affected by agenesis outside the cleft area in individuals with cleft lip and palate. The authors also reported high occurrence of agenesis of the lateral incisor at the non-cleft side and suggested that these cases may be considered incomplete forms of bilateral cleft lip. According to the authors, even though it may seem improbable that a single gene may affect the development of both the teeth and the palate, simultaneous presence of the cleft and tooth abnormalities may strongly indicate that a common genetic origin is involved and that a simple contribution of the gene should not be ruled out.

Similar to these findings and confirming the possible genetic etiology, hypodontia outside the cleft area was observed in 27% of children with clefts and 11% of their siblings, compared to only 3.6% in children without clefts (Eerens et al., 2001).

The knowledge that even a cleft with mild extent may be associated with the occurrence of tooth abnormalities highlights the importance of special care for patients with cleft lip and palate during the period of dentition development. Moreover, the accomplishment of orthodontic treatment in patients with clefts requires knowledge and special attention on their predisposition to present dental developmental disturbances, also outside the cleft region.

Tooth Abnormalities of Structure

Enamel alterations in the deciduous and permanent incisors are frequently observed in patients with cleft lip and palate [Dixon, 1968; Malanckzuk et al., 1999; Chapple and Nunn, 2001], especially when the cleft affects the alveolar ridge.

The structure of deciduous central and lateral incisors close to the cleft may be altered, presenting creamy-white or yellowish-brown opacities and hypoplasia. These enamel defects are observed at a significantly higher frequency on deciduous central incisors adjacent to unilateral clefts (64.5%) compared to the contralateral teeth (9.6%) [Maciel et al., 2005]. The

most prevalent type of enamel defect is the creamy-white opacity, primarily affecting the buccal aspect of the maxillary central incisor [Malanckzuk et al., 1999] (Figure 42). In bilateral clefts, one or both deciduous central incisors may be affected (Figure 43) and the risk of recurrence of these defects in the permanent dentition is nearly absolute (100%) [Malanckzuk et al., 1999].



Figure 42. Structural enamel alterations – creamy-white opacity and hypoplasia – on deciduous maxillary central incisor adjacent to the cleft in patient with complete unilateral cleft lip and palate.



Figure 43. Structural enamel alterations – creamy-white opacity and hypoplasia – in deciduous maxillary central incisors in patient with complete bilateral cleft lip and palate.

Concerning the chronology of formation of the deciduous maxillary central incisors, it is known that their calcification is initiated at the 14th week of intrauterine life and the enamel is complete at the age of one month and a half. Thus, the formation of enamel defects on these teeth occurs mainly during the prenatal period [Lunt and Law, 1974]. This reinforces the hypothesis of a common pathogenesis for clefting of the primary palate and odontogenic disorders on teeth adjacent to the cleft in both dentitions [Malanckzuk et al., 1999].

The literature has demonstrated that alterations in the enamel structure are also observed on the permanent central incisors adjacent to the unilateral alveolar cleft, even more frequently than on deciduous incisors [Malanckzuk et al., 1999; Maciel et al., 2005] (Figure 44). In individuals with complete unilateral cleft lip and palate, structural enamel anomalies were observed in 83.3% of maxillary central incisors adjacent to the cleft and in 25% of contralateral teeth [Maciel et al., 2005]. The most frequent defect was the creamy-white opacity, followed by enamel hypoplasia, primarily affecting the incisal third on the buccal aspect [Malanckzuk et al., 1999; Maciel et al., 2005]. In individuals with bilateral clefts, the incisors may be affected at one or both sides (Figure 45).

The higher occurrence of structural enamel defects on the permanent teeth may be explained by the fact that they are formed mainly during the postnatal period, thus being more sensitive to external harmful influences during their morphogenesis than the deciduous teeth, which are formed in the prenatal period and are protected in the womb. According to Nanci (2003), many environmental adverse conditions may cause defects on the enamel structure because the ameloblasts are particularly sensitive to changes.



Figure 44. Structural enamel alterations – creamy-white opacity and hypoplasia – in permanent maxillary central incisor adjacent to the cleft in patient with complete unilateral cleft lip and palate.



Figure 45. Structural enamel alterations – yellowish-brown opacity and hypoplasia – in permanent maxillary central incisors in patient with complete bilateral cleft lip and palate.

The influence of the genetic control on tooth development should also be considered. This control is mediated by complex interactions between the epithelium and the mesenchyme, by a network of signaling molecules and transcription factors that guide the cell proliferation and differentiation (odontoblasts and ameloblasts) and later the tooth mineralization [Bailleul-Forestier et al., 2008]. Failures in the functions of components involved in this process or gene mutations may give rise to defects in the dentin and enamel matrixes, causing congenital defects in tooth mineralization [Thesleff, 2006; Hu and Simmer, 2007].

Thus, even though the precise etiology of enamel abnormalities is not known, they may reflect environmental, systemic or genetic disorders, thereby requiring a detailed record of the clinical and family history of the patient and the potential exposure to environmental factors for the correct diagnosis.

The high prevalence of enamel alterations on the incisors adjacent to the cleft constitute a risk factor to dental caries and may also affect the esthetics. Therefore, the professionals should recognize the importance of early diagnosis to adequately perform the preventive follow-up or treatment of these alterations, when necessary.

Prevalence of Dental Caries in Children with Cleft Lip and/or Palate

The literature reports that children with cleft lip and palate exhibit increased risk to dental caries and high number of untreated cavities, especially in the deciduous dentition [Bokhout et al., 1996; Bokhout et al., 1997; Wong and King, 1998]. However, most studies on dental caries present methodological flaws, such as small sample size, inclusion of different age ranges, inclusion of patients with syndromes, inadequate or missing control groups, and failure to eliminate other influencing factors [Wong and King, 1998; Hasslof and Twetman, 2007a]. Recently, a well conducted literature review concluded that there are not

enough scientific evidences to safely support the assumption that children with cleft lip and palate present higher caries prevalence compared to children without clefts. However, the authors observed a tendency of higher caries rates in children with cleft lip and palate at preschool age, as well as the importance of anatomical and psychological risk factors in these patients, which influence the achievement of a good oral hygiene, making it more challenging [Hasslof and Twetman, 2007a; Hasslof and Twetman, 2007b].

Several reasons are related with these aspects. In children with cleft lip and palate, the morphological and structural alterations mentioned earlier in this chapter and the dental arch collapse may complicate the dental plaque control. The surgical scar and tension of the upper lip secondary to the primary repair restrict the access to the maxillary anterior teeth for both the patient and the dental professional (Figures 46a and 46b).



Figure 46. A) External view of operated upper lip, demonstrating excess of lip tissue. B) Internal view of operated upper lip, with presence of frenula and dental caries on deciduous maxillary central incisor and enamel hypoplasia on deciduous maxillary right canine.

Moreover, from a psychological standpoint, the parents have more difficulty to “say no” to children with congenital anomalies, being more permissive as to inadequate habits concerning both the oral hygiene and the ingestion of cariogenic foods [Hasslof and Twetman, 2007b].

In a recent study, Mutarai et al. (2008), intending to minimize the aforementioned methodological flaws, analyzed the prevalence of early childhood caries in children with clefts aged 18 to 36 months, compared to a control group of children without clefts matched for age, area of residence and educational level of the caretakers. The different types of clefts were analyzed individually. The results revealed that children with clefts presented higher dental caries experience than children without clefts. However, the type of cleft was not a significant factor influencing the caries prevalence, while night feeding was the most important aspect in the occurrence of early childhood caries in children with clefts. The authors suggested the combination of preventive oral hygiene protocols and emphasis on the dietary habits, especially by providing information to caretakers, to reduce the caries risk of children with cleft lip and palate.

What is the importance of all these aspects? A healthy dentition is fundamental for children with cleft lip and palate to allow better facial growth and development, avoid postoperative complications, and allow the accomplishment of orthodontic treatment before alveolar bone grafting and corrective orthodontic treatment. An adequate oral health also allows space maintenance and preservation of alveolar bone, which is fundamental at the region adjacent to the cleft.

Prevalence of Gingivitis in Children with Cleft Lip and/or Palate

The greater accumulation of dental plaque on the maxillary anterior teeth of children with cleft lip and palate also increases the occurrence of gingivitis at this region [Dahllof et al., 1989; Paul and Brandt, 1998; Costa et al., 2003]. However, studies comparing the composition of subgingival dental plaque in the deciduous dentition of children with or without cleft lip and palate did not find differences in the periodontal microbiota [Costa et al., 2003]. Moreover, a literature review demonstrated that patients with cleft lip and palate do not present higher probability to develop periodontal disease [Wong and King, 1998].

Children with cleft lip and palate may be considered a group at higher risk of plaque accumulation and development of gingival inflammation, especially at the region of the alveolar cleft. Thus, oral health maintenance in these patients requires their inclusion in preventive programs, aiming at the adequate oral hygiene control.

General Considerations

The occurrence of different types of tooth alterations in the deciduous and permanent teeth adjacent to the cleft is a characteristic condition in patients with cleft lip and palate and should be a matter of concern for the parents and professionals.

Therefore, dental professionals should have knowledge on these alterations in order to successfully provide information to the parents. The follow-up of health of the deciduous dentition is the indicated approach to maintain its good status, even in the case of supernumerary or malpositioned teeth, with a view to maintain the supporting bone structures, which may be defective at the region of the defect [Gomide and Costa, 2007].

Dental Treatment

The bone deficiency present in the alveolar ridge at the cleft area commonly gives rise to alterations of shape, number, position and structure of teeth adjacent to the cleft [Ribeiro et al 2003; Maciel et al., 2005; Tortora et al., 2008]. The fibrotic scar on the lip may impair the oral hygiene at this region; also, the fear to cause injury to the operated area predisposes to the accumulation of plaque and presence of caries on these teeth [Castilho et al., 2006] (Figure 47).

The extraction of teeth at the cleft area is commonly indicated, especially when these teeth are positioned in areas that complicate the access to restoration, or when orthodontic tooth movement is not indicated due to the lack of bone at the region (Figure 48).

However, maintenance of these teeth is important for maintenance of the surrounding alveolar bone, avoiding the increase in size of the bone defect at the cleft area. Some professionals fear to perform dental treatment on these teeth; however, provided some particularities are observed during application of local anesthesia and placement of the rubber dam, the treatment may be conventionally performed.



Figure 47. Decayed teeth at the cleft area.



Figure 48. Deciduous tooth ectopically erupted at the cleft area.

Anesthesia at the Cleft Area

In the presence of complete cleft lip or complete cleft lip and palate, the maxilla is divided in two or three segments, depending on the extent of the defect (Figures 49 and 50). Before the onset of treatment at the cleft area, the dental professionals should observe the segment in which the tooth is implanted, because the innervation is independent between the segments. Therefore, it is advisable to take a radiograph of the tooth to be treated to define the exact site of implantation (Figure 51a, 51b and 51c).



Figure 49. Complete unilateral cleft lip and palate; the maxilla is divided into two segments.



Figure 50. Complete bilateral cleft lip and palate; the maxilla is divided into three segments.



Figure 51. Lateral incisor located at the cleft area. The intraoral aspect does not clearly demonstrate the site of tooth implantation, yet the radiographic examination reveals implantation on the posterior segment. A) Buccal view. B) Palatal view. Notice also the T-shaped central incisor. C) Radiographic aspect.



Figure 52. Complete bilateral cleft lip and palate, exhibiting the prolabium adhered to the gingiva and absence of buccal sulcus.

However, when the tooth is located in the center of the cleft, both segments should be anesthetized [Dalben et al., 2000]. The application of local anesthetics at the cleft area may cause great discomfort and pain to the patient, due to the presence of lip fibrosis, which complicates the injection of anesthetics. Patients with unoperated clefts often exhibit lack of the buccal sulcus, which further increases the pain at this region (Figure 52).

The local anesthesia should be carefully applied, in order to minimize the discomfort to the patient. It should be initiated by careful air-drying of the region, followed by application of topical anesthetics and slow injection of the anesthetics. The needle should be positioned following the tooth long axis, previously determined on the initial radiograph (Figure 53a to 53j).



Figure 53. (Continued).



Figure 53. (Continued).



Figure 53. (Continued).



Figure 53. A) Right lateral incisor at the cleft area indicated for extraction. B) Panoramic radiograph. C) Periapical radiograph. D) Drying. E) Application of topical anesthetics at the site of puncture. F) Puncture following the tooth long axis. G) Inclination of the needle to complement the anesthesia on the adjacent segment. H) Complementation of anesthesia on the adjacent segment. I) Papillary anesthesia on the buccal aspect. J) Papillary anesthesia on the palatal aspect.

Restorative Treatment of Teeth Close to the Cleft Area

The restorative treatment of teeth adjacent to the cleft area is not different from the restorative treatment of any other tooth. These teeth exhibit the same anatomical structure as the others; the only difference is their location at a region with poor quantity of alveolar bone, ectopically positioned, which often impairs the access to treatment. However, after careful evaluation of the cost-benefit relationship to maintain this tooth, the treatment may be conventionally performed, using the same restorative materials routinely employed in the dental clinics. Since teeth at the cleft area often exhibit abnormalities of shape, the clinical examination may not be sufficient to indicate if the tooth is deciduous or permanent. Therefore, a periapical radiograph should be initially taken for differential diagnosis, since the treatment may be different in the case of pulp involvement.

Placement of rubber dam is always indicated for the treatment of these teeth; however, depending on their location, this may not be possible. The rubber dam may be placed using clasps or dental floss. If the rubber dam may not be used, the dental professional should carefully use cotton rolls and suction to keep the operative field dry (Figure 54a to 54j).



Figure 54. (Continued).

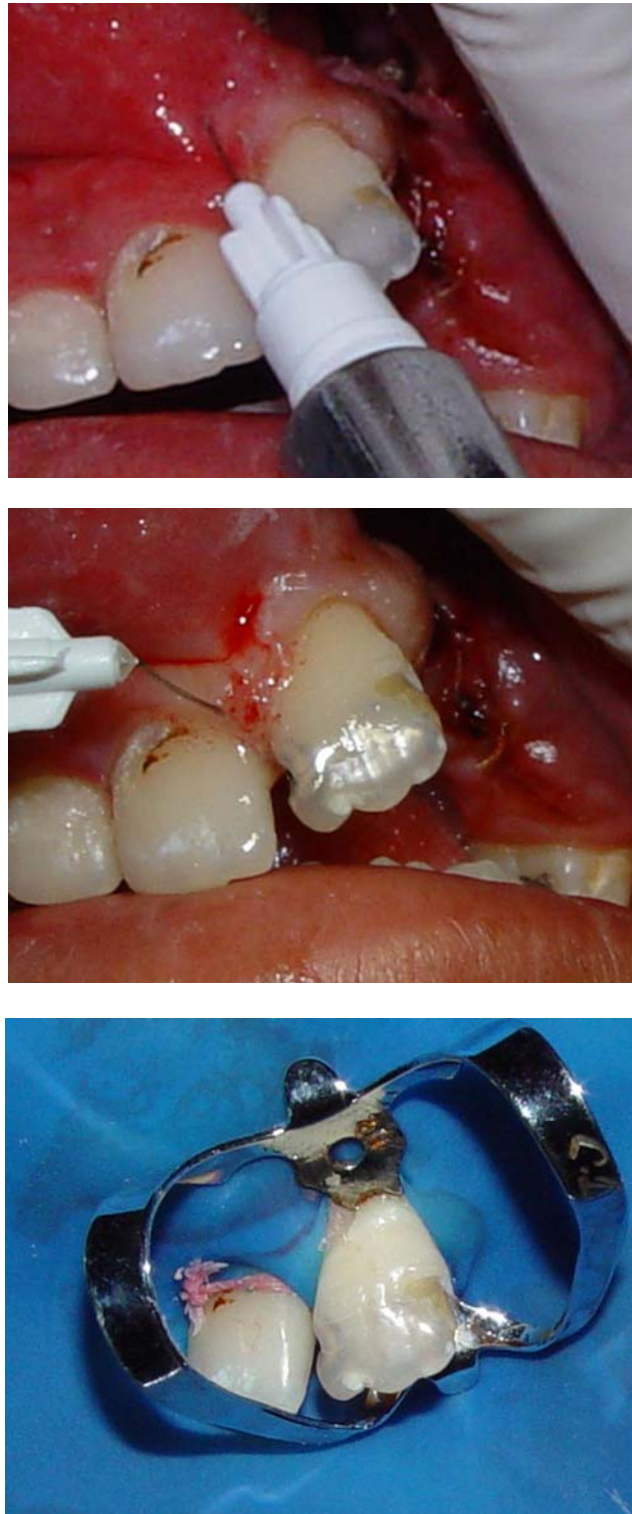


Figure 54. (Continued).



Figure 54. (Continued).

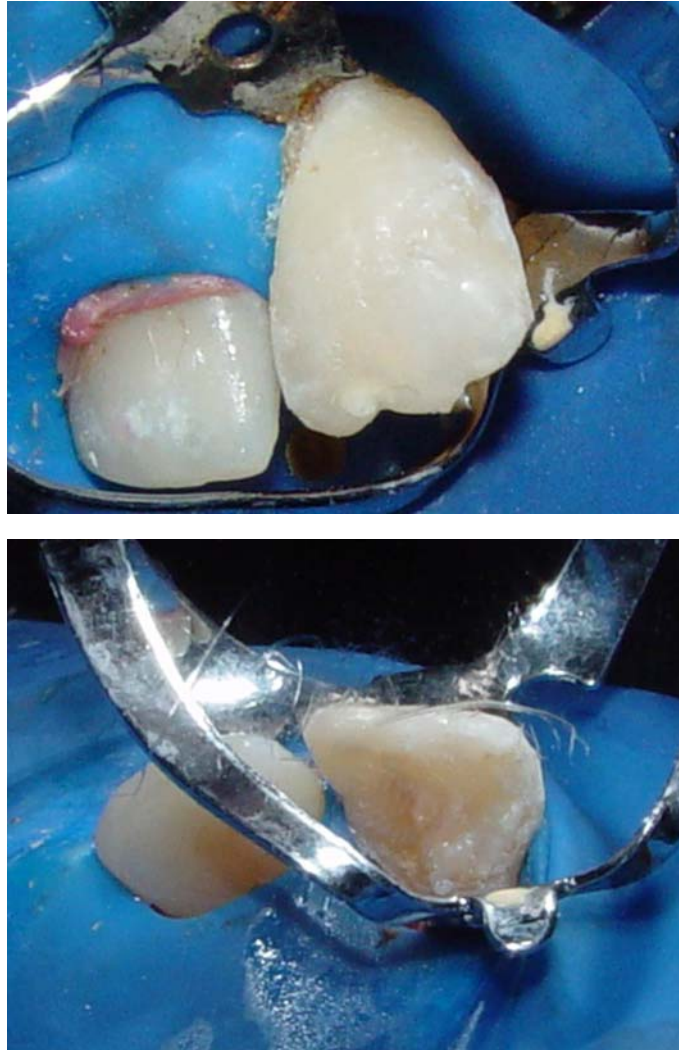


Figure 54. A and B) Maxillary left central incisor adjacent to the cleft with indication for restoration (buccal and palatal views). C) Infiltrative anesthesia. D) Papillary anesthesia. E) Isolated tooth, buccal view. F) Isolated tooth, palatal view. G and H) Removal of decayed tissue and cavity lining with calcium hydroxide cement. I and J) Completion of restoration (buccal and palatal views).

Tooth Extraction at the Cleft Area

The extraction of teeth at the cleft area is similar to the procedures applied to patients without clefts. Radiographic examination of the tooth to be extracted is the first step to determine its correct location, detect possible root dilacerations and evaluate the extent of the carious lesion [Dalben et al., 2001]. Adequate application of local anesthesia is fundamental for tooth extraction and should be performed following the aforementioned considerations.

The extraction of teeth erupted at the cleft area follows the same steps adopted for extraction of any other tooth: syndesmotomy, luxation, grasping with the forceps, extraction and suture (Figure 55a to 55e).



Figure 55. (Continued).



Figure 55. A) Syndesmotomy on the buccal aspect. B) Syndesmotomy on the palatal aspect. C) Placement of the forceps. D) Extraction. E) Suture.

During tooth extraction in patients with unrepaired cleft palate, care should be taken to avoid tooth displacement to the palate and consequent aspiration by the patient. This may be avoided by placing a gauze close to the cleft area. Moreover, during extraction the tooth should not be displaced toward the cleft area. The pressure should be applied in opposite direction to the cleft, thus avoiding displacement into the cleft area [Dalben et al., 2001].

After extraction, curettage of the socket is performed, followed by irrigation with saline and suture. The suture is fundamental to avoid a possible hemorrhage in the cleft area, which may be hardly detected by visual inspection.

Dental Treatment before Accomplishment of Repair Surgeries

The important role played by the regular dental treatment for children with cleft lip and palate (CLP) is well known [Dungy, 1976; Rivkin et al., 2000a; Zschieschack and Grabowski, 1999]. The study conducted by Ranalli et al. in 1984 has shown that many post-graduation programs in Pediatric Dentistry include clinical training in patients with CLP, especially restorative pediatric dental procedures, space retainers, and orthodontic treatment. However, even though the treatment needs of these patients are similar to patients without clefts [Dungy, 1976], many dentists feel insecure to provide dental care to these patients [Dias et al., 2001].

Concerning the child behavior in the dental clinic, the accomplishment of many surgical procedures in the oral region may lead the parents to be overprotective and may also give rise to dental fear in the children; therefore, dental professionals must know how to manage these psychological aspects [Ranalli, 1981; Rivkin et al., 2000a]. For the same reason, the parents may not consider the importance of oral care [Ranalli, 1981; Ranalli and Zullo, 1986], even though some authors state the opposite [Rivkin et al., 2000a]. Thus, the parents may not search for regular dental follow-up and may often miss the scheduled consultations [Ranalli and Zullo, 1986].

The standpoint of parents about the dental treatment of their children with CLP was assessed by McDonagh et al. [2000]. The results of this study revealed that, even though most parents appreciate the dental treatment and prevention provided at cleft centers, they prefer to search for dental treatment at their cities of origin.

In any case, the successful dental care for children with CLP requires collaborative work between all dental specialties, as well as patient compliance with oral hygiene control at home [Waurick, 1979]. All restorative procedures provided should have high quality [Rivkin et al., 2000b], particularly before surgeries for lip and palate repair, since carious lesions are a possible source of infection and may compromise the expected surgical outcome. This is especially important before secondary surgeries in older patients, who already have many teeth erupted in the oral cavity and may have carious lesions. The dental care provided before surgery should remove all possible sources of infection represented by active carious lesions. Furthermore, the treatment should have high quality and definitive restorations should be placed, in order to avoid the need of re-intervention during the first months postoperatively, when healing is taking place.

Following, this chapter will present the case of a boy who needed lip repair and restorative dental treatment, as well as the description and sequence of dental procedures performed. The boy exhibited complete bilateral cleft lip and palate and initially attended the cleft center for treatment when he was a baby. At five months of age, lip repair was performed only at the left side, according to the surgical protocol proposed at that time. Due to financial and family problems, he returned to the cleft center only at the age of eight years, when he and his family wished to perform lip repair at the right side, as well as the primary palate repair.

Figures 56 to 58 demonstrate the initial dental status of the child. Regardless of his age, because he had never been submitted to any dental treatment, a psychological preparation

session was performed using the “Tell-show-do” method before onset of the restorative procedures, in order to show the dental equipments and explain their functioning and purpose (Figure 59).

After all sessions, the child received a balloon or paper pictures for painting, independently of his behavior during the session yet highlighting the moments of good compliance.



Figure 56. Oral status at treatment onset (frontal view).

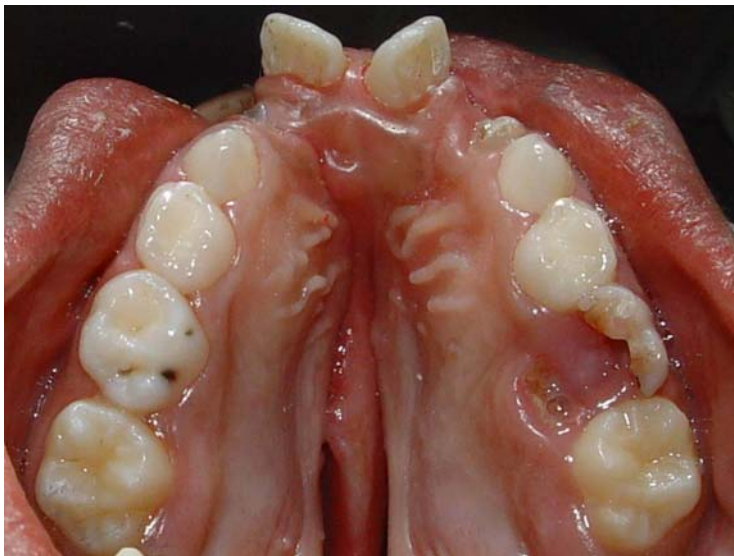


Figure 57. Status of maxillary teeth.



Figure 58. Status of mandibular teeth.



Figure 59. Psychological preparation: demonstration of dental equipments.

Since this psychological preparation session was uneventful, the restorative procedures were initiated on the following session. The boy needed small and extensive restorations and tooth extractions. The treatment planning was initiated by the smallest procedures, allowing the child to get accustomed to the dental care.

As previously mentioned in this chapter, anesthesia at the cleft area may cause discomfort to the patient and should be avoided at the first sessions. For the same reason, the procedures should be initiated on the maxillary arch, since the child may feel more comfortable with maxillary infiltrative anesthesia compared to inferior alveolar block. Therefore, the first procedure comprised restoration of the deciduous maxillary right second molar. Application of topical anesthetics before the injection is fundamental to reduce the

discomfort (Figure 60). In the maxillary arch, local anesthesia should also be applied on the palatal aspect of teeth before placement of the rubber dam and clasp (Figure 61). The first lesion was small and received an amalgam restoration, because of the durability of this material and considering the high caries risk of the boy (Figure 62). It should be highlighted that utilization of the rubber dam is very important in all dental procedures, moreover in patients with cleft lip and palate [Dungy, 1976] and especially in patients with an unrepaired cleft palate, in order to prevent accidental aspiration or swallowing.

On the following session, since the patient compliance was very good, mandibular alveolar blockage was performed and the entire hemiarch was treated at once, in order to save chair time. At this session, amalgam restorations were applied on the deciduous mandibular left first and second molars (Figure 63).



Figure 60. Application of topical anesthetics before the injection.



Figure 61. Anesthesia of the palatal aspect for placement of rubber dam and clasp.



Figure 62. First restorative procedure – amalgam restoration on the deciduous maxillary right second molar.



Figure 63. Amalgam restorations placed on the same session on the deciduous mandibular left first and second molars.

Subsequent treatments comprised extraction of the deciduous maxillary left second molar during one session, and restoration of the deciduous mandibular right canine and second molar and extraction of the deciduous mandibular right first molar on another session. Whenever possible, tooth extractions should be made after the restorative procedures, so that the child may already be accustomed to the dental treatment.

Figures 64 and 65 demonstrate the final dental status, after accomplishment of dental treatment.

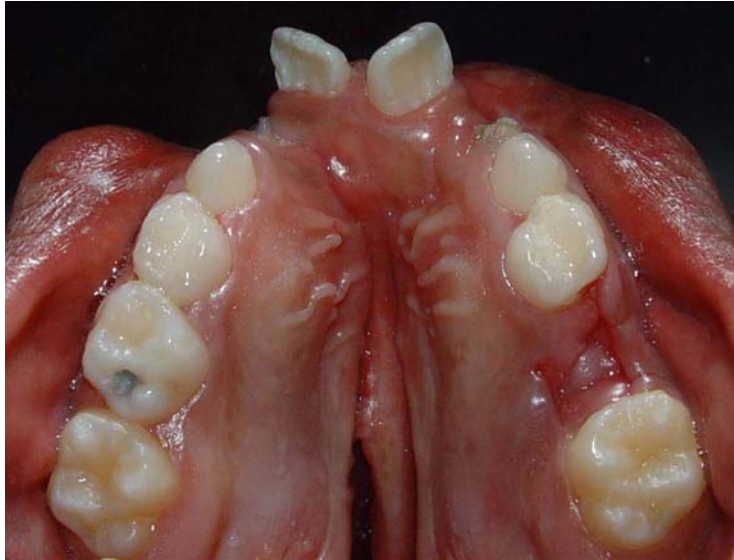


Figure 64. Final status of maxillary teeth.



Figure 65. Final status of mandibular teeth.

Due to the need of general anesthesia for the surgical procedure, some dental procedures may be performed simultaneously under general anesthesia [Rivkin et al., 2000b]. The patient also needed extraction of the deciduous maxillary right and left lateral incisors at the cleft area, bilaterally. Since this procedure might cause discomfort and the patient would undergo general anesthesia for surgery, these teeth were extracted under general anesthesia immediately before the lip repair (Figures 66 and 67).



Figure 66. Application of general anesthesia for lip repair, during which tooth extraction was also performed.



Figure 67. Final aspect after extraction of the deciduous maxillary lateral incisors at the cleft area bilaterally.

In the present case, the extraction of teeth close to the cleft area was performed immediately before the lip repair. The opportunity to extract these teeth under general anesthesia is convenient. In this case, it was possible due to the need of lip repair. If the patient requires extraction of more maxillary teeth, the dentist and the plastic surgeon should discuss the case individually. Depending on the surgical technique and the tissue available, the extraction of several teeth, especially in the maxilla, should be performed a couple of weeks before the surgical procedure.

Considerations about Orthodontic Treatment

From the standpoint of orthodontic treatment, individuals with isolated cleft lip without involvement of the alveolar ridge or with isolated cleft palate do not present any disorder related to the cleft, except for occasional rotated or malpositioned teeth at the cleft lip area in the former. For these individuals, the orthodontic treatment may be planned and conducted as routinely applied for individuals without clefts. For this reason, this chapter presents only some considerations about orthodontic treatment for individuals with cleft lip and alveolar ridge or with complete cleft lip and palate, who are orthodontically managed in a similar manner.

The maxillary growth in individuals with clefts is impaired both by the presence of the cleft and by the several reparative plastic surgeries required. The cleft influences the maxillary growth due to the bone defect, causing deficiency in the width, height and thickness of the alveolar ridge. The extent of this influence depends on the width of the cleft and presence of a soft tissue bridge [Capellozza Filho et al., 1996]. The influence from the surgical treatment on the maxillary growth varies according to the number of surgical procedures required for cleft repair, surgical techniques employed, as well as the surgeon's skill [Ross, 1987; Semb, 1991a; Semb, 1991b; Capellozza Filho et al., 1996].

Due to the unfavorable long-term outcomes observed in patients with cleft lip and palate submitted to preoperative orthopedics, this approach currently is not applied in many cleft centers worldwide [Pruzansky, 1964; Gnoinski, 1982; Cavassan and Silva Filho, 2007]. For this reason, the orthodontic treatment may be initiated in the late deciduous or early mixed dentition stage [Cavassan and Silva Filho, 2007], especially after eruption of the permanent maxillary first molars, considering the high prevalence of impaction of these teeth on the distal aspect of the deciduous maxillary second molars, probably caused by the reduced retromolar space in the maxilla [Silva Filho et al., 1990; Silva Filho et al., 1996].

The treatment of individuals with clefts is planned in two strategic periods, namely before and after secondary alveolar bone grafting [Cavassan and Silva Filho, 2007]. The accomplishment of secondary alveolar bone grafting was a great achievement in the treatment of individuals with clefts affecting the alveolar ridge, since this procedure restores the continuity of the alveolar ridge [Bergland et al., 1986; Enemark et al., 1987; Semb, 1988].

The treatment is initiated by orthopedic maxillary expansion for lateral repositioning of the palatal segments, which are usually palatally displaced causing maxillary atresia, in both complete unilateral and bilateral cleft lip and palate. This atresia may also be evident in the sagittal direction in individuals with complete unilateral cleft lip and palate; in the presence of a Class III interarch relationship, the orthopedic maxillary expansion may be followed by maxillary protraction, before the accomplishment of secondary alveolar bone grafting.

In individuals with complete clefts, the expansion actually occurs by lateral displacement of the palatal segments rather than by opening of the midpalatal suture, as observed in individuals without clefts; therefore, no diastema is opened between the maxillary central incisors. The posttreatment stability is very poor, since at this stage the maxilla is still divided in two or three bone segments due to the presence of unilateral or bilateral clefts, respectively. Therefore, a fixed retainer must be placed until bone grafting is performed, which will finally provide the bone continuity and stability required for the continuity of

orthodontic treatment. The bone grafting allows subsequent accomplishment of orthodontic treatment as conventionally applied for individuals without clefts [Bergland et al., 1986; Enemark et al., 1987; Semb, 1988; Cavassan and Silva Filho, 2007].

Figures 68a to 72b present the sequence of orthodontic treatment applied to a patient with complete bilateral cleft lip and palate, according to the aforementioned considerations.



Figure 68. Initial aspect of infant with complete bilateral cleft lip and palate. A) Extraoral view. B) Closer view.

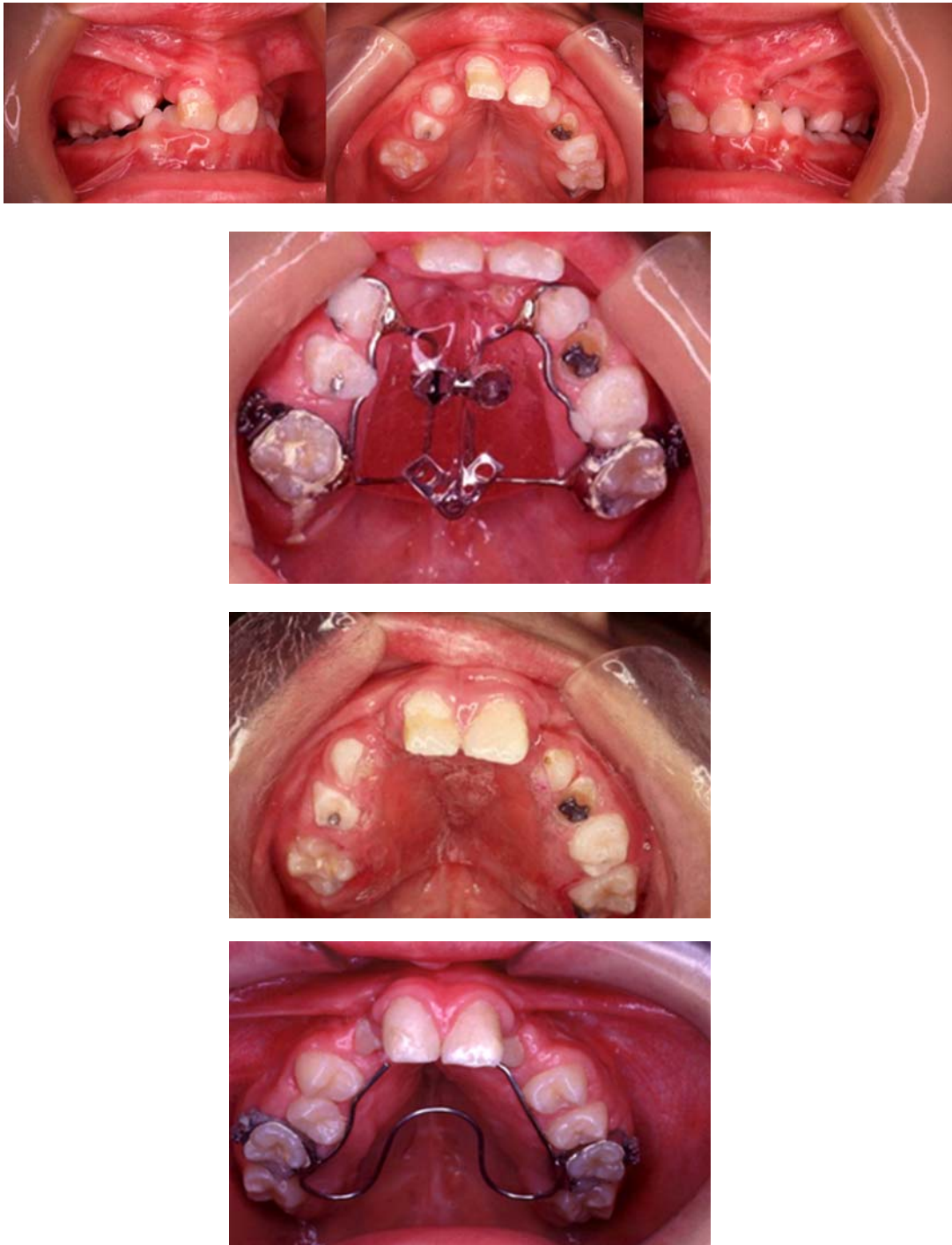


Figure 69. A) Intraoral aspect of same patient in the mixed dentition stage evidencing the maxillary atresia, especially at the canine region. B) Expander appliance in place, with special design for the achievement of expansion only at the canine region. The subsequent treatment comprised additional expansion using a conventional expander. C) Aspect after expansion. D) Fixed retention for maintenance of the outcome of expansion.



Figure 70. A) Occlusal radiographs evidencing the bone defect at the cleft area, bilaterally. B) Aspect after alveolar bone grafting.

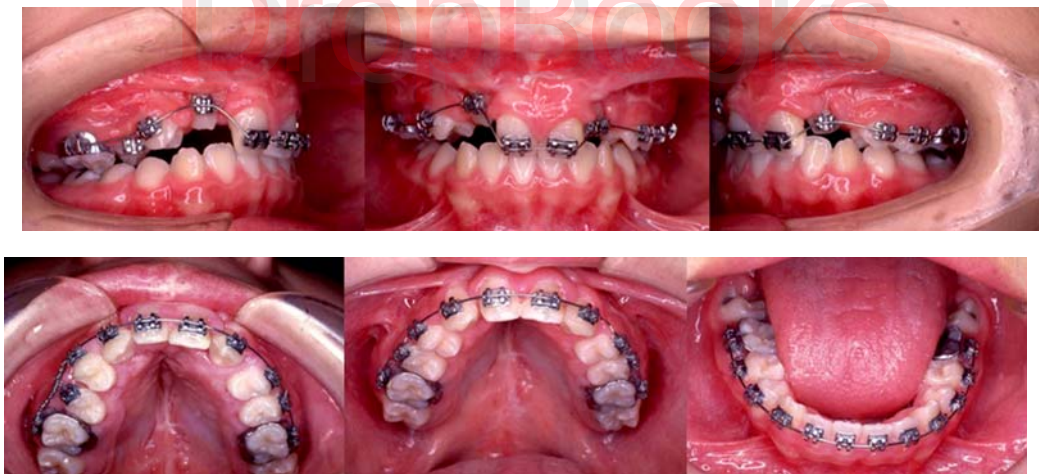


Figure 71. A) and B) Aligning and leveling after alveolar bone grafting.



Figure 72. A) and B) Final treatment outcome.

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Chapter 9

The Use of Artificial Intelligence for Diagnosis and Treatment Planning in Orofacial Disharmonies

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Abstract

Recognition of orofacial disharmonies and offering appropriate treatment plans according to their signs and symptoms are intelligent actions which are normally performed by a dentist. Using their knowledge and analyzing power, dentists distinguish the signs of the underlying diseases. Can we help dentist in diagnosis and treatment planning using a computerized algorithm? That is the question we are trying to address using intelligent agents. Basically, an intelligent agent is a component that has its own knowledge and owns enough intelligence to analyze it. Using object oriented theory in the computer science, we can model any intelligent agent in an object that has its own "properties and methods". We are trying to find a solution model using the necessary knowledge in the form of "properties of an object". On the other hand, by means of artificial intelligence algorithms, we will make the methods of mentioned object to form "intelligent behavior" for it. The result would be an intelligent agent that takes its required data from different sources like patient, processed images or the dentist. Based on gathered data, the intelligent agent processes the information internally to deliver its findings either as a diagnosis or treatment plan; or as a clue for dentist to do more investigations.

1. Introduction

In this article we're trying to make a general model to implement intelligent software which can help a dentist (or a physician in more general idea) to diagnose diseases and/or offer treatment plan for it.

To make this model, we define an abstraction that has two basic characteristics: First it is intelligent; second it can learn to be more intelligent. We call this abstraction an "Intelligent Agent". By intelligence, we mean it can have a "judgment" or can offer a "plan" based on its input. At the first levels, the judgment may not be very reliable but the model provides a mechanism to make better judgments and/or plans as it learns more during the time. The learning happens when the dentist feeds the agent with the result of its judgments or plans in the real world.

To design the basic software component for our intelligent agents, we use object oriented methodology as a powerful method to create such abstraction. We also utilize neural networks as a tool to implement intelligent behavior for our objects. How sophisticated would be our first implementation? It depends on first design ideas behind it but we try to make it more and more intelligent using Loss function to minimize its error. We define this behavior "learning".

As a case study and to make our model more sensible we try to design a software component that offers treatment plan for an orthodontic case. In our design, we use the mentioned model and create a neural network and loss function which can help us to solve our problem in that specific case.

2. What is Artificial Intelligence

Facing problems, we generally try to solve them. This may vary from a very simple action to very complicated ones containing step by step calculations, reasoning or logical deductions. Although there is no universally accepted definition for intelligence [1], we can consider these actions as intelligent ones.

Intelligence is naturally found in human or in animals in specific cases. We consider this sort of intelligence as natural intelligence but when we utilize science or engineering to create intelligent machines, we have created artificial intelligence [2]. This would be an intelligent machine which is a system that perceives its environment and takes actions which maximize its chances of success [3].

From above definition, we can see that artificial intelligence definition could be beyond computer science alone, but since computer software can provide best environment for such machines, it is considered as a branch of computer science. In this article we'll use computer science and technology that take intelligent actions to provide dentists with diagnostics or treatment plans.

3. Intelligent Agents

Our base elements which process the input and produce the result are intelligent agents. We use object oriented methodology to design these basic elements. In the following sections, we will explain the design of our basic intelligent elements.

3.1. Object Oriented Programming

"Object Oriented" is a paradigm that tries to model everything in the form of objects and their interactions. Attempts to find a unique definition or theory behind objects has not been very successful [4] but it has been commonly used since 1990s and it has been getting more and more popularity in recent years as it has shown its power in the design and implementation of computer programs. In this methodology, class is an abstraction that encapsulates properties and behavior of all instances of that class. Each instance is called one object. In other words, class shows the type of an object.

In software implementation, properties and behavior of objects can be modeled using member variables and methods of the class respectively so a class has two fundamental parts: member variables and methods.

There can be relations between different classes. One of the most important relations between classes is inheritance. A class can extend a base class by inheriting its properties and methods and then changing those methods or by adding new properties and methods to it.

For example, the "Creature" can be the base class for all living objects in the world. We can extend it by inheriting two new classes - "Human" and "Animal"- from it. Animal can be extended by inheriting classes like "Cat" and "Dog" from it so each cat in the world would be an instance of the class "Cat". In this example, each cat would have behaviors of the class "Cat" and also all behaviors from the "Animal" and "Creature" classes would be inherited to each instance of the class "Cat".

3.2. Implementing Intelligent Agents Using Object Oriented Methodology

As mentioned, we have selected Object Oriented methodology to prepare our base design. In our design we have one base intelligent agent which we have implemented it in a class called "NeuralAgent".

The "NeuralAgent" class uses a neural network to distinguish the disease or the necessary plan for treatment. It contains two main properties. One property is symptoms which in fact are holding the input used for diagnostic process. There should be necessary "getter" and "setter" methods for this property that could be found in the appendix A. The other property is the Neural Network which will be used to diagnose or choose the treatment plan. This property holds the main essential information for the class to do its task. This property - which is from the type of Neural Network - contains the *predesigned* network that makes the intelligence of the class. In fact, it contains the intelligence and knowledge of

designer to show how to achieve our goals based on provided input. In the next section, we will briefly discuss how such network can be designed.

"NeuralAgent" class has two main methods: Learn and Loss Function. After diagnosis, the physician feeds the class with the result of its job with a number we call it "Acceptable Value". This number will be used by the class to learn how to make better results.

The procedure of learning takes place by calculating a loss function and trying to minimize it. The Learn method uses "LossFunction" method each time the class is fed with a new acceptable value and then tries to change its neural network to minimize the total loss using all the results that have been provided to it. That is why we have a property called "AcceptableValue" in the symptom class. This property gets its value after the physician feeds back the system with the rate of success.

As mentioned previously, the neural network is stored as a property in the class but it may change during the time as the class learns from the success rate of its diagnosis. In other words, each time a physician gives an acceptable value to a diagnosis (or treatment plan); the class would recalculate the loss function and tries to change its neural network to minimize the loss function for all cases.

Since all cases and their acceptable values - and the neural network of our "Neural Agent"- are necessary for next jobs and they may change during the time, the class should store those data into a persistent media like hard drive. That is why we have designed Persist and Load methods for this class. Load method is called each time the class is loaded into the memory and Persist method is called after recalculating the loss function and changing the neural network of the class.

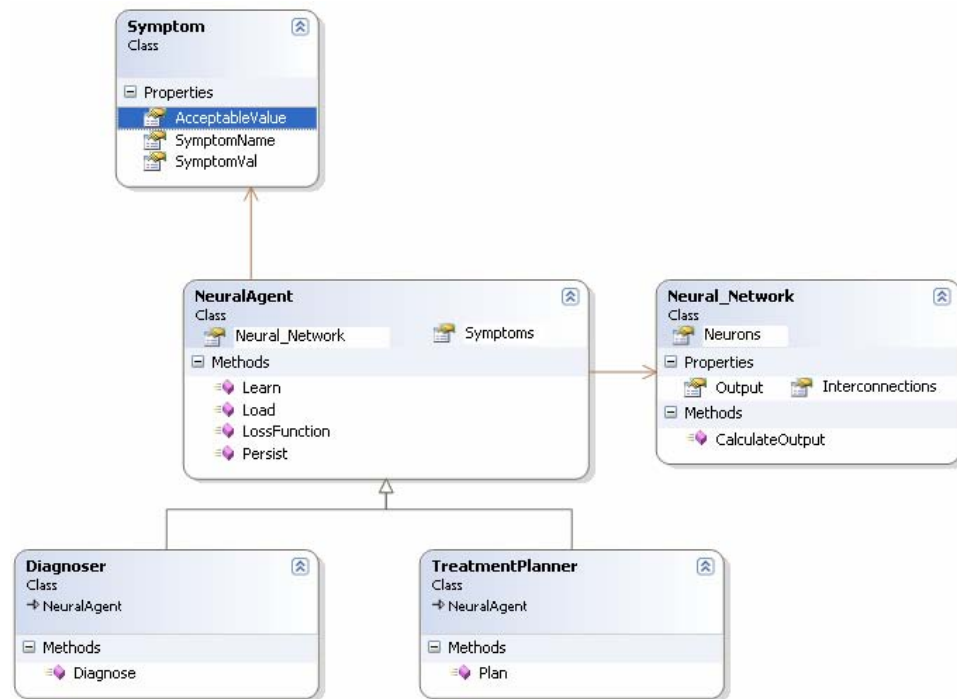


Figure 1. Base design class diagram.

Since our intelligent agent can be used to diagnose a disease or offer a treatment plan, we have extended two different classes from this base class to achieve two new different classes for the mentioned purposes. As discussed in the last section, we can do this kind of extension by inheriting two new classes from the base class. These two new classes will inherit all methods and properties from the base class and may add new methods or even make modification in some methods of the parent class.

The Diagnosing class will add a method called "diagnose" and the "TreatmentPlanner" class will add a method called "Plan" to the base class. This is just a schematic separation of these two procedures. However, they both do the same job; they use the neural network and the input symptom to offer the output.

For each case of Diagnosis or Treatment, the implementation of Loss Function and the design of neural network would be different. We will discuss the Loss Functions and Neural Networks in the following sections and will design these two in a practical case in the last section. Figure 1 shows the classes and their relations in our basic design.

3.3. Using Neural Networks to Make an Object "Intelligent"

There are several approaches toward artificial intelligence. Search and optimization, fuzzy logic, probabilistic methods, statistical methods, neural networks and control theory are some of different methods to implement artificial intelligence [5-10]. Neural networks are one of the most useful approaches in this regard. "An artificial neural network (ANN), also called a simulated neural network (SNN) or commonly just neural network (NN) is an interconnected group of artificial neurons that uses a mathematical or computational model for information processing based on a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network". [11]

In software engineering, a neural network is a set of programs and data structures that intends to simulate the operation of the human brain to do an intelligent task. Typically a neural network has two phases of training: An initial training at the time that software is coded and a gradual training during the life of system. [12]

As we discussed in the previous section, we use a pre-designed (or pre-wired) artificial neural network to make our agents an intelligent diagnoser. This prewired neural network acts like a prewired circuit or as a brain that our "Diagnose" method uses to do its job. In this section we will briefly show how such wiring of an artificial neural network can take place.

Artificial neural networks contain a network of basic elements called "artificial neurons" or "nodes". Each artificial neuron or node processes its input and produces an output which could be used as an input to the next node based on network topology. The whole networks simulate a biological network of neurons that work together to form an intelligent result.

Each artificial neuron or node does a simple process: it calculates its output using a formula which is a weighted sum of its inputs. It is simply shown in figure 2.

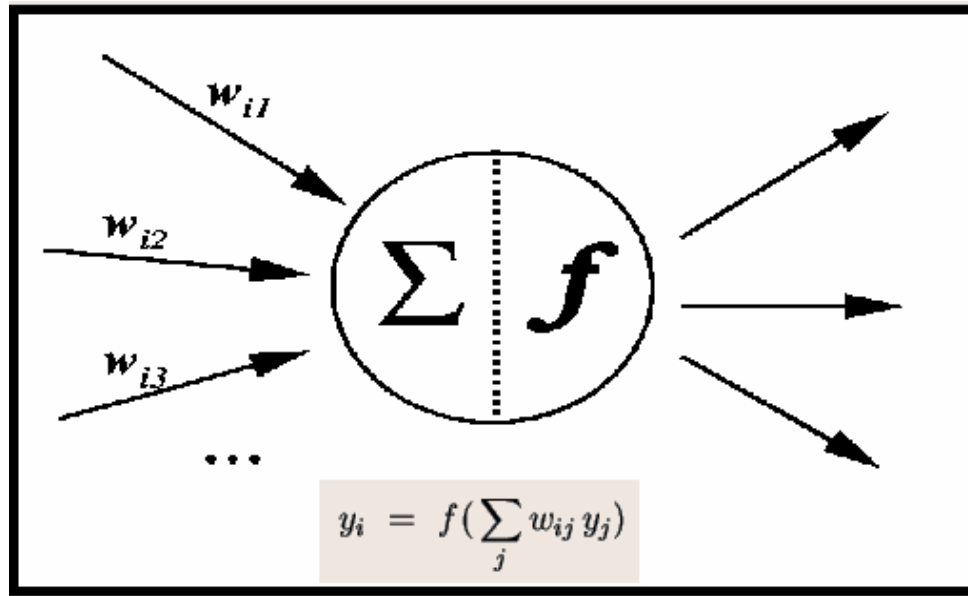


Figure 2. How a typical artificial neuron calculates its output.

To design an intelligent network, first we need to design our basic neurons and define their output function. Then we should design the interconnection between the neurons to produce the planned output.

Such network calculates a final output based on its input. The output would be a number which can be used as an indicator of a treatment plan or disease number.

In our base design, we create three classes to form a neural network. The first class is the “Neuron” class which implements a linear neuron with one output and contains its node number and the weights of its inputs as main properties. We hold the current input of the neuron in the “Inputs” property. There should be necessary getter and setter method for these properties in a real implementation. The main method is “CalculateOutput” method which calculates the output of the node based on inputs and their weights.

The interconnection of the nodes can be stored in the instances of the class “Interconnection”. This class stores information about the nodes that it connects them tighter in the properties “FromNode” and “ToNode” and the input number of destination node in a property named “InputNo”. This class has a main method with the name of “Relay” and its task is to change the input value of destination neuron based on output value of the source neuron.

The class “NeuralNetwork” implements a simple linear network and holds two main properties with the names of “Neurons” and “Interconnections”. The first property is an array of the class “Neuron” and the second is an array of the class “Interconnection”. It has a main method called “CalculateOutput”. This method calls the same method for all neuron inside its network. After running the “CalculateOutput” of the neurons, the “CalculateOutput” method of the network will call “Relay” method of all Interconnections inside its network. We call these two actions as “NetworkCycle”. After running a network cycle, the network output gets a value. The “CalculateOutput” method of the network will continue running cycles until we

get a stable output for the network. We will have a stable output when it does not change after running two consequent cycles.

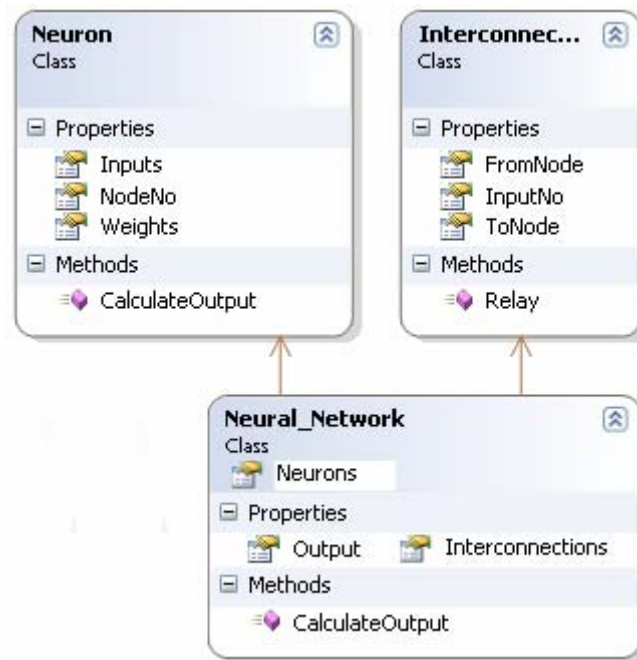


Figure 3. A simple linear neural network class diagram.

When the output value of the networks is calculated, we use it as an index that shows the diagnosis or treatment plan. We will show an example of this procedure in the next section. Figure 3 shows our base class diagram for implementing a neural network. The base implementation can be found in the appendix B, although the detailed implementation is beyond the scope of this article.

3.4. How to Make Intelligent Objects a “Learner” Using Loss Functions

For each case, we collect a set of inputs and feed it into "TreatmentPlanner" object. Treatment planner will use its neural network to calculate the output which is the parameter that shows the selected plan. What we can optimize in this scenario is the weight which is used in each node or neuron. We can change the weights to optimize the result. To optimize them, we can feed the system with the acceptable value of each case.

With each new input, we recalculate all weights and store new results in the system. With this method we will optimize our planning method. In other words our intelligent agent is learning how to give better plans during the time.

When defining the network, the designer gives the initial weights to each neuron but he/she can give the allowed range for each weight as well. The Learn method of our intelligent agent tries to change all weights in the allowed range and it will choose a set of

weights which minimize the loss function. This new set will be stored and used for the next diagnosis or treatment planning procedure.

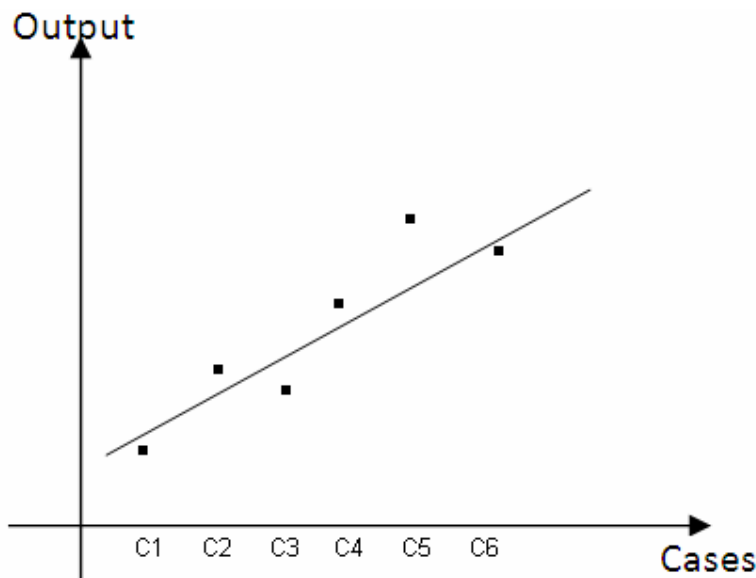


Figure 4. A diagram representing a loss function.

As a simple form of a loss function we can use sum-squared error function which is a linear function like this: $Y = \frac{1}{2} \sum (\text{AcceptableValue} - \text{OutputValue})^2$

The following diagram shows we can draw a line to minimize the above loss function. In this diagram each case of acceptable value is shown as a dot. The drawn line passes near all dots in a way that the above error function outputs the least value.

By finding values that minimize the loss function, we can adjust the input weights of our linear neural network. We consider this adjustment as learning, because it helps the class to give better results in the next case.

4. Case Study: Implementing an Orthodontic Treatment Planning Intelligent Agent Called "OTPIA"

In this section, we will utilize the idea mentioned in the previous sections to create a treatment planner to decide whether to "extract the teeth or not" for orthodontic purposes. For example, to resolve mandibular crowding in an orthodontic case, we are not usually allowed to expand the dental arch because it produces unstable results. [13-16] Stripping can also provide some space, but is not a favorable method due to the damage it causes to the enamel. Protruding the lower incisors more than 2 mm also brings about unstable conditions. [17] If we assume that each millimeter of incisor protrusion increases the arch perimeter about 2 mm [18], it can be said that if the amount of crowding in a quadrant is less than 2 mm (i.e., less

than 4 mm in a jaw), orthodontic treatment can be performed without any extraction in that quadrant, provided there are not any dental protrusion/ retrusion or midline deviation. But if the crowding is more than that, or if there is dental protrusion or midline deviation, we usually need to extract a premolar to provide space for canine retraction in order to correct crowding, incisor protrusion and midline deviation.

Based on the amounts of needed canine retraction (CR) and total crowding (TC), we may offer four different treatment plans as defined in the following algorithm:

If $(TC \leq 2) \Rightarrow$ Offer Plan1 (non-extraction)

If $(TC > 2)$ and $(CR < 2) \Rightarrow$ offer Plan 2 (extraction of first premolar with minimum anchorage)

If $(TC > 2)$ and $(2 \leq CR < 4) \Rightarrow$ offer Plan 3 (extraction of first premolar with moderate anchorage)

If $(TC > 2)$ and $(CR \geq 4) \Rightarrow$ offer plan 4 (extraction of first premolar with maximum anchorage)

In the above algorithm, values 2 and 4 are border values for the parameter "CR" which determines the final decision for the offered algorithm. How can we implement the above algorithm using mentioned classes and can we change those border values to give more precise plans? These questions will be answered in the following sections.

4.1. OTPIA Neural Network

We can design a simple linear neural network for this case as can be seen in figure 5.

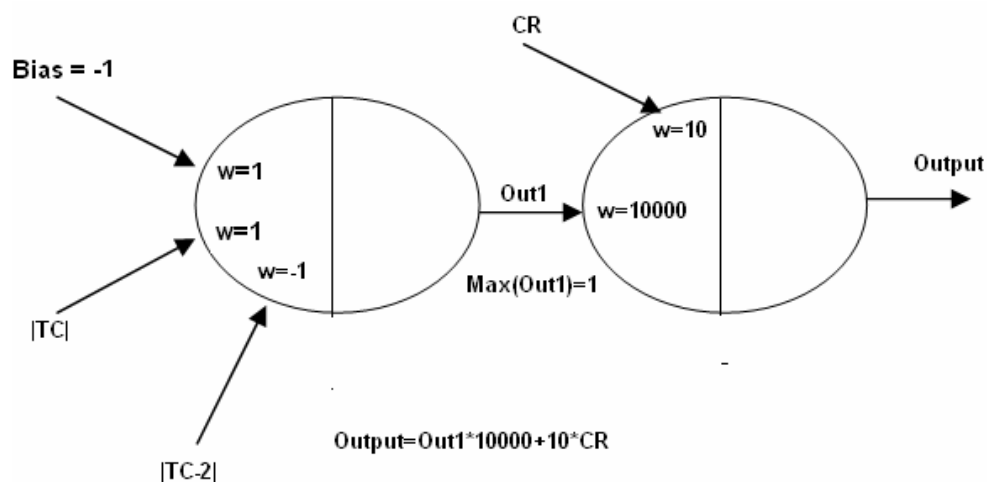


Figure 5. A simple linear neural network for our case study.

In the above network we have considered one input as bias which always has the value of -1. The maximum value for output of left neuron happens when $TC=2$ and it is 1. For $TC>2$ the output remains at 1 but for the $TC<2$ the output will be less than 1. The total output of above neural network will be: $Output = Out1*10000 + 10* CR$ (Note: $Out1 \leq 1$).

Assuming that the steps of TC values are not less than 0.01, the maximum value for the output of first neuron would be 0.98 which will be multiplied by 10000 to become 9800. If we assume that the biggest value for CR is 20, the output of system would be always less than 10000, provided the value of TC is less than 2.

With the above network we can expect the results to be less than 10000 if $TC<2$. So we can deduce the following formulas:

$Output < 10000 \Rightarrow \text{offer Plan1}$

$10000 \leq Output < 10020 \Rightarrow \text{offer Plan2}$

$10020 \leq Output < 10040 \Rightarrow \text{offer Plan 3}$

$Output > 10040 \Rightarrow \text{offer Plan4}$

4.2. OTPIA Loss Function

To reduce the error during the learning process, we need a loss function. We define the sum-squared error function as the loss function for our case. We also consider the allowed range for weight of CR in the second neuron from 5 to 20. Then the border values for CR (2 and 4) could be adjusted in the learning process.

Assuming $w=5$ for the weight of CR, we will get 10020 when $CR=4$ and we will get 10040 when $CR=8$. Assuming the maximum weight of 20, we will get 10020 when $CR=1$ and will get 10040 when $CR=2$. By changing the weight, the first border value changes from 1 to 4 and the second border value from 2 to 8.

In this example, we are trying to learn which border values are more suitable for our plan selection. As mentioned earlier, we first chose the border values of CR as $b1=2$ and $b2=4$ but letting the weight of CR change during the learning process, the border values may change to be adjusted based on real scenarios. So $b1$ can change between $1 < b1 < 4$ and $b2$ will change between $2 < b2 < 8$.

Conclusion

Fuzzy logic concept has already been used to develop orthodontic software. [19, 20] In this article we tried to show that Artificial Neural Networks (ANN) can also be used to diagnose the diseases or to suggest treatment plans. One of the most important advantages of neural networks in solving such problems is their “learning” characteristics using loss functions.

To show how we can use ANN to offer a treatment plan more clearly, we used object oriented methodology and created a base design and documented our design using class diagrams. As a sample, we discussed OTPIO case and used a very simple linear neural network to offer treatment plan. We also showed how the system may learn during the time to produce more effective plans.

Moving forward, we can use more complicated neural networks to give our base design “more intelligence”. Using multiple output neurons and complex neural networks, we can create a platform for parallel processing for the cases that need huge amount of processing power to finish the calculations. Creating more effective loss function would be another area for research to improve our base design learning capability.

Appendix A

In this section we are showing the function declaration for our base design classes using C# language.

```
public class Symptom
{
    public int SymptomName { get{};set{} }

    public int AcceptableValue { get{};set{} }

    public int SymptomVal { get{};set{} }
}
public class NeuralAgent
{

    public Symptom Symptoms { get{};set{} }

    public Neural_Network Neural_Network { get{};set{} }

    public void Learn()
    {
        // Changes the weight of neural network input in the allowed range and tries to minimize
        // the loss function
    }

    public void LossFunction()
    {
        //A sample:  $Y = \frac{1}{2} \sum (AcceptableValue - OutputValue)^2$ 
    }

    public void Load()
```

```
{
// Loads neural network from disk and sets the Neural_Network property
}

public void Persist()
{
//Saves the neural network to disk
}
}

public class Diagnoser : NeuralAgent
{

public void Diagnose()
{
// Uses neural network and current symptom to produce the output
}
}

public class TreatmentPlanner : NeuralAgent
{

public void Plan()
{
// Uses neural network and current symptom to produce the output
}
}
```

Appendix B

In this section we are showing the function declaration for our base design for neural network classes using c# language.

```
public class Neuron
{
public int NodeNo { get{};set{} }

public int Inputs { get{};set{} }

public int Weights { get{};set{} }

public int CalculateOutput()
{
//calculates the ouput based on input values and weights
}
```

```

    }
    public class Interconnection
    {
        public int FromNode { get{};set{} }

        public int ToNode { get{};set{} }

        public int InputNo { get{};set{} }

        public void Relay()
        {
            // Changes the input value of input number InputNo of the destination node
        }
    }
    public class Neural_Network
    {
        public Neuron Neurons { get{};set{} }

        public Interconnection Interconnections { get{};set{} }

        public int Output { get{};set{} }

        public int CalculateOutput()
        {
            //It runs mutiple network cycles until makes sure the output will not change with running
            // a new network cycle. In each network cycle it runs the CalculateOutput method of all
            //neurons inside object and then calls all relay methods of interconnctions inside it
        }
    }

```

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Chapter 10

Down Syndrome: Need for Jaw Stabilization to Prevent Dysphagia

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Abstract

Swallowing is a complex, highly-coordinated activity. In the presence of neurodegenerative pathologies, inability to perform safe swallowing can lead to pulmonary infection by aspiration of respiratory pathogens. The risk is decreased by regular oral hygiene and rehabilitation of jaw stabilization, which improves the first step of swallowing. Mandibular stability is achieved by providing maximum congruency of articulating joint surfaces, ie optimized type and number of dental inter-arch contact units (ICUs) at the end of the jaw closing movement. Many anatomic, congenital, developmental or acquired conditions weaken the stable support base provided by the ICU joint surface and so prevent mandible bone stability. Lack of stability can be caused by tooth loss, often present in elderly persons, and by massive oro-facial dysmorphology such in Down Syndrome. Here we argue for the need to maintain or rehabilitate dental occlusion in Down Syndrome subjects to facilitate the prevention of aspiration pneumonia.

Keywords: Down Syndrome, jaw stabilization, dysphagia, prevention.

Introduction

Swallowing is a complex, highly coordinated activity. It transports liquids and food particles from the oro-pharyngeal space to the esophagus, while preventing potentially catastrophic entry of food particles or liquids through the airways and into the lungs. In

vulnerable subjects, inability to perform safe swallowing can be congenital, developmental or acquired. Swallowing disorders can be observed in many case of neurological disorder inducing peripheral or central neuro-motor disability, such as cerebral palsy, stroke, Parkinson's disease, Alzheimer's disease or Down Syndrome [1-12]. This dysfunction induces recurrent food or liquid aspiration. In the case of large particles, aspiration may lead to asphyxiation if the subject is unable to expel the foreign body by coughing. Thus if the local anatomic conditions required for safe swallowing are not met in contexts of neuro-motor disability, swallowing disorders may be worsened and lead to fatal outcome [13-18]. In the case of liquid or small particles, aspiration may lead to pulmonary infection. The oral cavity has long been considered as a potential reservoir of respiratory pathogens [19]. The mechanisms of infection could be aspiration into the lung of oral pathogens capable of causing pneumonia, colonization of dental plaque by respiratory pathogens followed by aspiration, or facilitation by periodontal pathogens of colonization of the upper airway by pulmonary pathogens²⁰. Recent hypotheses concern the presence in saliva of enzymes and cytokines associated with oral pathogens, which may modulate the colonization of the respiratory tract or promote infection by respiratory pathogens [19, 21]. Hence changes in dental plaque, oral microbial flora, and local oral immunity [22] may be important in the development or exacerbation of diseases in critically ill patients [23-24], trauma patients [25], adults with chronic obstructive pulmonary disease [26], and frail persons [27-29]. Accordingly, numerous authors underline the need to improve oral hygiene among patients who are at risk as Down syndrome subjects [14, 20, 30]. Adjustments in treatment and management strategies may be necessary for patients presenting these diseases and impairments [30]. The risk is thereby decreased, but not totally eradicated. Other factors must be also controlled. Many microbiologic and epidemiologic studies point to an association between chronic obstructive pulmonary disease (COPD), number of functional inter-arch dental units (ICUs) and toothlessness [14]. Loss or absence of ICUs increases the risk of dysphagia [31]. Rehabilitation of occlusion allows mandible stabilization, which is necessary for an efficient first step of swallowing [16]. Also, rehabilitation of dysfunctional chewing/swallowing function is possible only if mandible stabilization is effective. For Down Syndrome subjects, our purpose here is to present arguments in support of mandible stabilization before any rehabilitation of swallowing. The prevention of dysphagia and AP could thereby be facilitated.

Factors Controlling Jaw Stability

Local Anatomic Conditions

The mandible is connected to the skull by two joints: the temporo-mandibular joint (TMJ) and the dento-dental joint made up of ICUs (figure 1). These two joints allow the mandible to move in three functional planes of motion: jaw-closing/jaw-opening motions, left and right latero-trusive motions, and retrusive-protrusive motions.

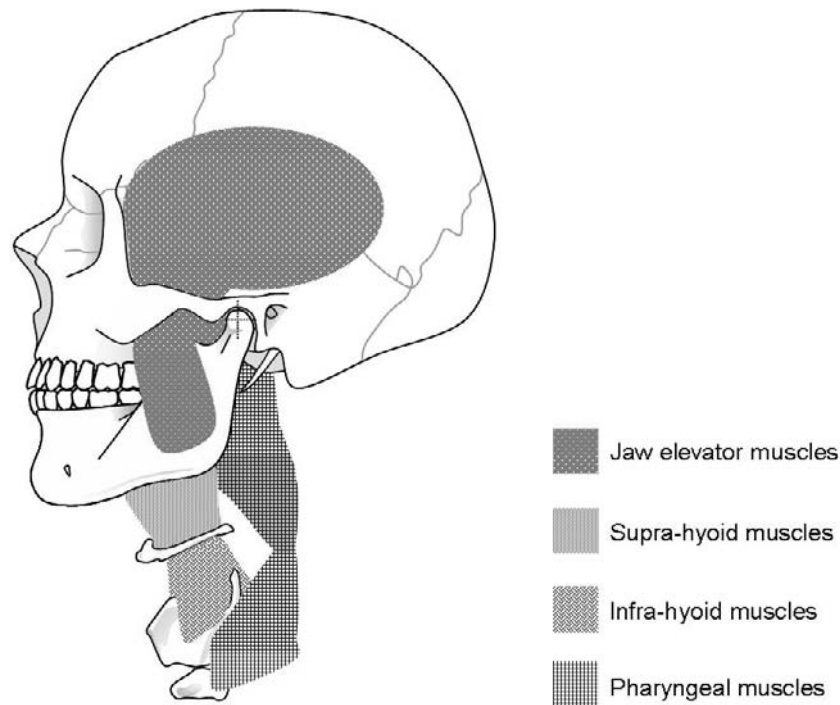


Figure 1. In the muscular chain of deglutition, mandible stability, obtained *via* jaw elevator muscle contraction and ICUs, is the first step in safe adult swallowing.

Joint stability can be divided into passive stability, defined as passive handling of the limb by someone else, and functional stability, defined as (i) static stability and (ii) dynamic stability. Concerning the skull-mandible connection, the structures assumed to provide joint stability are teeth, and muscles and ligaments [32-33]. Mandible stabilization consists in providing joint functional stability in dynamic and static jaw activity. Here we focus on the static functional stability of the mandible. Dynamic stability allows isotonic contraction. It consists in maintaining maximum congruency of the articulating joint surfaces during mandible excursive movements. It is obtained by co-activation of antagonist muscles during active joint mobilization and thus keeps joint stability by opposing displacements induced by agonist muscles. Static stability allows isometric muscle contraction. When teeth are contacting, occlusion helps to maintain mandible bone stability by opposing displacements induced by jaw-closing muscle activity (figure 1). Number, quality, and distribution of the ICUs are conditions for an efficient anatomic obstacle that stiffens the skull-mandible connection during jaw-closing muscle contraction. The joint locking thus obtained ensures mandible bone stability in a load-bearing position. First, bone stability allows high force production during jaw-closing muscle contraction, necessary for food crushing. It attenuates strain for TMJ ligaments, and limits muscle fatigue in isometric contraction, as described for other groups of muscles [34]. Second, mandible bone stability allows infra-mandibular swallowing-related muscles to contract and achieve safe adult deglutition. Masseter activity, improved with mandible bone stability obtained *via* ICUs, helps the supra-hyoid muscles to pull the hyoid bone upward (figure 2), the infra-hyoid muscles to contract (figure 3) and the pharyngeal phase of the swallowing to take place [35-38].

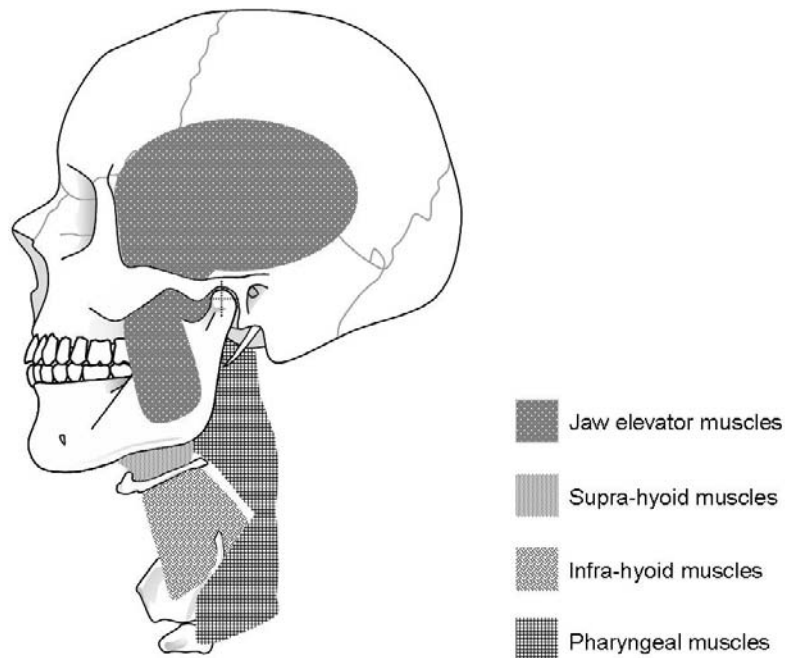


Figure 2. Mandible stability allows the supra-hyoid muscles to contract and pull the hyoid bone upward.

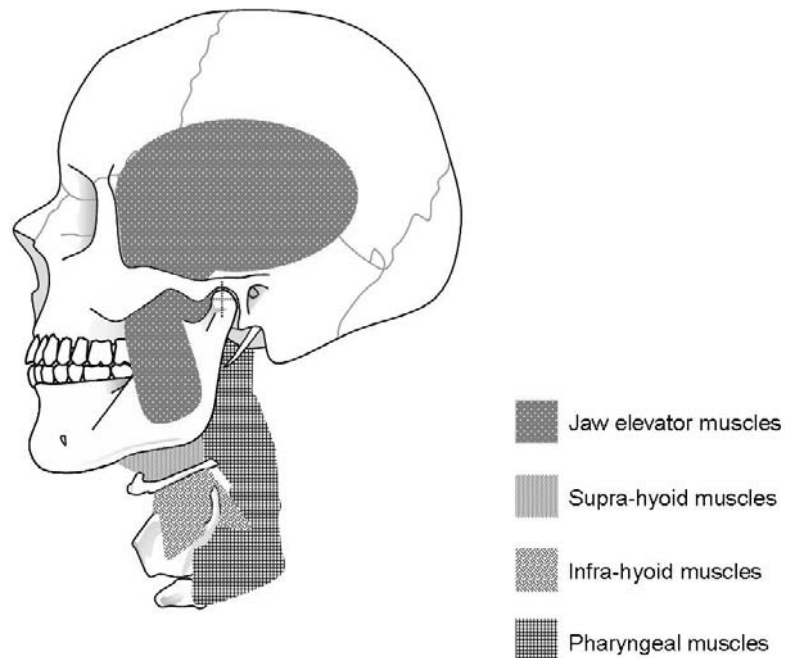


Figure 3. Once the hyoid bone is stabilized, the infra-hyoid muscles contract, the larynx is pulled anteriorly, and the pharyngeal phase of the deglutition proceeds.

The Role of Inter-Arch Dental Contacts

Mandibular stability is achieved by providing the maximum congruency of the articulating joint surfaces, ie optimized type and number of ICUs at the end of the jaw closing movement. Optimized dental inter-arch contacts thus provide conditions close to isometric contraction for jaw-closing muscles.

The quality and quantity of periodontal proprioception modulates the recruitment of muscle fibers during the isometric contraction of jaw muscles. This modulation is described in the work of Lund and Lavigne [39-40], and in studies on orthognatic surgery, which highlight a correlation between the number and (or) surface area of the dental inter-ach contacts and force production during isometric contraction [41-42].

If the dental arches do not allow the dento-dental joint to lock, the force production decreases.

Factors Affecting Jaw Stability

Many authors have studied force production in three different situations: (i) when the jaw position is shifted, (ii) in cases of malocclusion, (iii) when occlusal interferences are artificially created.

The Role of Jaw Position

In subjects with normal occlusion, when the jaw is in the retruded contact position [32, 43] and in the latero-trusive position [44-46] the force production of masseter and temporal muscles in maximal voluntary contraction (MVC) is decreased compared with force production in MVC in centric occlusion. This can be explained in three different ways:

- When the jaw position is shifted, the number of dental inter-arch contacts is decreased compared with centric occlusion, and their distribution is asymmetric. This induces mandible instability at the end of jaw elevation, when teeth are contacting. This can explain the decrease in muscular unit recruitment [32-47].
- Force production and muscular activity in MVC vary according to their point of load on the arch. In centric occlusion, maximal muscle force is developed in the molar region, and decreases when applied on more anterior teeth [46]. When the jaw position is shifted, the biting point may not be centered in the molar region, and the force production then decreases [46, 48-49].
- Force production during isometric contraction depends on the initial length of the muscle. Owing to the sarcomere force-length relationship, the isometric force after active shortening and active stretching of muscles is respectively lower and higher [50]. The initial length of skeletal muscles depends on the bone positions at the beginning of the contraction. Thus the force developed by the jaw closing muscles

during isometric contraction depends on the mandible position relative to the skull at the beginning of the contraction, ie when teeth are contacting [32,44-45,49,51-52].

Malocclusions and Artificial Interferences

Different types of malocclusion have been studied: cross-bite, severe crowding, Class II division 1 with deep anterior overbite *versus* controls with normocclusion [53-55]. These reports describe a decrease in the activity of masseter and temporal muscles during chewing and swallowing. They also note asymmetry between left and right side in muscular contractions. The same kind of asymmetry is described when subjects clench in the lateral mandibular position [56]. The working-side activity of the temporal muscle is higher than its non-working side. This difference in the amount of muscular activity is decreased on introducing experimental non-working contacts.

Malocclusion has also been studied *via* experimental interfering occlusal contacts in normally dentate persons. Sheikholeslam and Riise (1983) [57] observed a decrease in jaw-closing muscle activity during MVC, and a decrease in the right-left symmetry muscular activity.

Consequences of Mandible Instability

Many anatomic, congenital, developmental or acquired situations weaken the stable support base provided by ICU joint surface and preclude mandible bone stability. Lack of mandible stability can be encountered in tooth loss. The lack of mandible stability cumulated with swallowing and feeding difficulties is also encountered in non-compensated massive oro-facial dysmorphology such as in Down syndrome.

Mandibular Stability and Swallowing

In adult swallowing, tooth contacting is a part of the deglutition chain that moves the liquids or masticated bolus from the mouth to the pharynx and then to the esophagus. During the first step of deglutition, the intra-oral space is depressed. The mandible is stabilized by ICUs brought together by jaw-closing muscles, the lips seal and the tongue muscles push the tip of the tongue against the palatal surface. The tongue then pushes the bolus into the pharynx, and the pharyngeal phase of the deglutition begins. From this phase on, deglutition cannot be interrupted voluntarily. The muscular sequence that follows is a very complex mechanism involving numerous pairs of pharynx, larynx and esophagus muscles. Their coordination, together with inhibition of respiration, prevents the bolus or liquids from entering the airways. Some of these muscles are skeletal muscles, inserted on the mandible, hyoid bone or larynx cartilages, achieving isotonic contraction and so allowing bolus propulsion. Thus mandible stability is a starting point for sub-mandible skeletal muscle contraction, hyoid bone rising, and sub-hyoid skeletal muscle contraction (figures 1, 2 and 3).

When mandible stability *via* ICUs is lacking, subjects adapt their deglutition chain by interposing their tongue between their dental arches [37, 58] as in infantile swallowing. Mandible stability is then obtained by increasing muscular activity.

Lack of mandible stability in subjects with neuro-motor deficiency, and therefore lack of coordination between swallowing and breathing, is a supplementary risk factor for aspiration. Terpenning et al (2001) [14] highlighted a relation between the number of ICUs and the occurrence of aspiration pneumonia in community-living and institutionalized older people. Tamura et al (2002a) [37] reported an improvement in swallowing in edentate elderly persons wearing the Swalloid appliance. Dahan and Lelong (2003) [59] highlighted an improvement in swallowing function, *via* a decrease in tongue thrust, on increasing dental proprioception in children.

Samuels and Chawick (2006) [60] evaluated the predictors of asphyxiation risk in adults with intellectual disabilities and dysphagia. Variables identified as predictors included maladaptive eating strategies (cramming and rushed eating) and premature loss of the bolus into the pharynx. Variables that did not predict asphyxiation risk included a visual evaluation of chew function (no oral preparation of the bolus: 0, some oral preparation of the bolus: 1, rotary movement of the jaw: 2, functional chew: 3) and number of “usable” teeth. However, the authors did not evaluate the number of ICUs, and masticatory function was summarily evaluated. Also, rushed eating and cramming can be associated with poor masticatory efficiency and with lack of ICUs [61-62]. Tamura et al (2002b) [16] highlighted a relation between mandible stability and the ability to swallow in a repetitive saliva swallowing test in institutionalized elderly persons. Hildebrandt et al (1997) [31] evaluated the relation between number of ICUs and complaints about chewing and swallowing in the elderly. They found that a low number of ICUs was related to aspiration of solid and liquid food and choking when eating, leading to food avoidance. Also, if mandible stability is not achieved, mastication is less or not efficient⁶¹. Subjects then have to swallow a bolus that has not been reduced enough to be safely swallowed, thus increasing difficulty of swallowing. First, persistent difficulty swallowing induces dysphagia. Patients may experience pain while swallowing, and may be completely unable to swallow. Eating then becomes a challenge. Second, improperly achieved deglutition may lead to aspiration pneumonia or asphyxiation.

Mandibular Stability and Chewing

Crushing food begins when the mandibular arch comes into contact with food. At this time, the jaw closing velocity is very low and the displacement needed to achieve food breakdown is also very short. The closer the situation is to the isometric condition, the more the jaw-closing muscles will exert a high force. Quality and quantity of ICUs are then necessary to ensure high-load food crushing, for mechanical joint locking and as mechano-receptive afferents. In addition, a correlation between masticatory efficiency and number or area of post-canine ICUs has been established [63-66]. A lack of mandible stability will then prevent subjects from performing proper mastication. Two strategies of adaptation can be applied: either the subject increases the time for food mastication in order to obtain the same food comminution, or the subject will swallow incompletely crushed food. In this last case,

the bolus consistency is not correct for safe swallowing, and has numerous adverse effects on the digestive tract [67-69]. Another consequence of an unsuitable bolus consistency is an increased risk of aspiration pneumonia [70], leading to respiratory infection or asphyxia.

Accumulation of difficulties in mastication and deglutition may have catastrophic outcomes.

Conclusion

In Down-syndrome, monitoring oral health is a significant factor in preventing dysphagia. This requires not only ensuring oral hygiene but also supporting or rehabilitating functions of mastication and swallowing. Jaw stabilization is possible by conservation or creation of maximum posterior dental contact. This rehabilitation can require complex dental treatments such as the fitting of devices or dentures. Hence the role of dental practitioners in the prevention of dysphagia and pulmonary infections is essential.

Case Report

The impact of mandible stability on recurrence of aspiration and its utility before any rehabilitation of swallowing can be illustrated by case reports. One such concerns a 19-year-old man with Down syndrome. He was addressed to the Special Needs Unit of the Dental Department at the University Hospital of Clermont-Ferrand (France) for dysphagia. He recently had a critical aggravation of his dysphagia following a series of aspirations during meals. After one of these aspirations, he was hospitalized for asphyxiation. This episode had dramatic consequences on his quality of life because of the functional and psychosocial impact. This young man was working in a specialized occupational center for the disabled. After his hospitalization, he refused to take meals in the staff canteen. The fear of aspiration and risk of asphyxiation during meals caused him to stop working and obliged his parents to keep him at home. Stopping work had a marked negative impact on his social integration, which had been quite good, and on the lifestyle of his family.

Clinical examination showed the characteristic oro-facial features of Down syndrome [1-58], with, as a consequence, unstable occlusion leading to propulsion mandible in habitual posture (figures 4a and 4b).

The objective of the treatment was to stabilize mandible posture by increasing posterior ICUs by means of an orthetic device (table 1) [61,71]. Increasing mandible stability was expected to optimize chewing and swallowing, before reeducation (figures 4c, 4d, and 4e). Improvement of chewing would lead to safer swallowing by a decreased particle size in the swallowed bolus. Mandible stabilization would facilitate swallowing. Reeducation was conducted after fitting with the orthetic device, consisting in tongue mobility exercises to improve tongue control and decrease fear during swallowing.

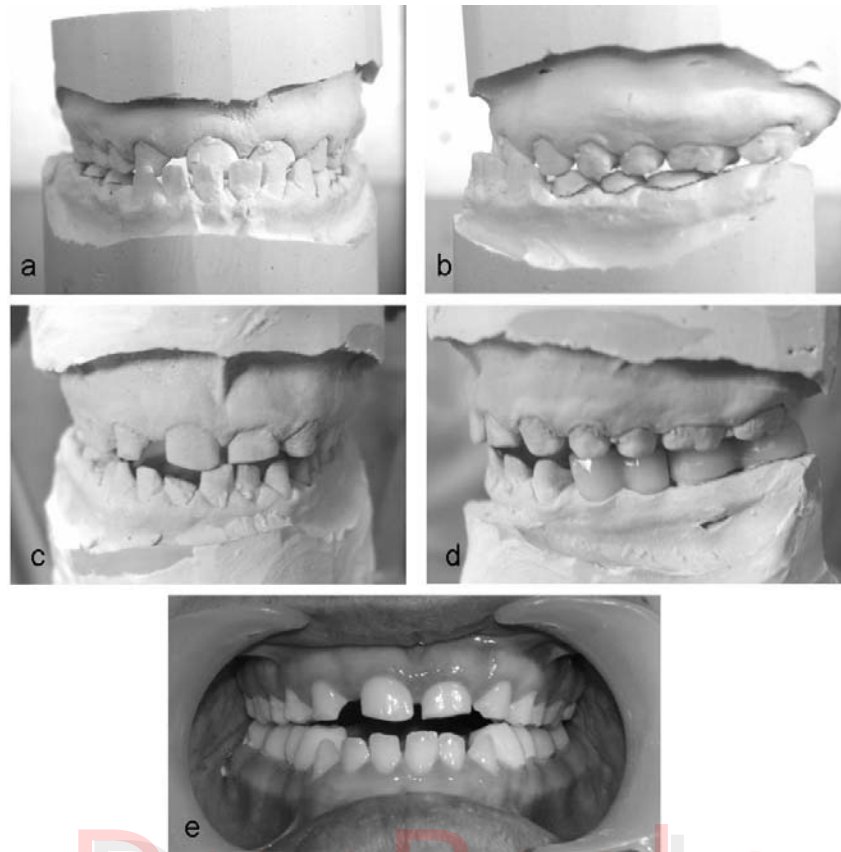


Figure 4. 4a: Plaster cast of the pretreatment intra-oral status of our patient. Front face view. Note the inversed occlusion. 4b: Plaster cast of the pretreatment intra-oral status of our patient. Lateral view. Note the propelled mandible position. 4 c: Plaster cast of the intra-oral status after orthetic device fitting. Front face view. 4 d: Plaster cast of the intra-oral status after orthetic device fitting. Lateral view. Note the retruded mandible position. 4 e: Intra-oral view of our patient after orthetic device fitting. The orthetic devices are fixed on mandibular molars and premolars.

Table 1. Number of ICUs before and after fitting with orthetic device in habitual posture and in centric relation

	Before treatment		After treatment	
	Habitual posture	Centric relation	Habitual posture	Centric relation
Number of ICUs	2	0	8	8

Chewing efficiency was evaluated by video assessment and granulometry [61, 72-73]. Video evaluation showed an improvement in the video masticatory parameters after fitting with the orthetic device, particularly for number of cycles and time of chewing of the harder test foods (carrot, peanut and jelly) (table 2).

Before orthetic treatment, the young man refused to eat one portion of peanut and two portions of carrot. After treatment, no food was refused.

Table 2. Video variables: number of chewing cycles, masticatory time and masticatory frequency before and after device fitting

Food	Before treatment			After treatment		
	Number of chewing cycles	Masticatory time (s)	Masticatory frequency (Hz)	Number of chewing cycles	Masticatory time (s)	Masticatory frequency (Hz)
Banana	11.5	11	1.07	11.5	12	0.96
Apple	16.5	15.5	1.09	16	14	1.13
Peanut	35	44	0.8	50	60.5	0.81
Carrot	26	44.5	0.53	41.5	59.5	0.71
Jelly	14.5	11.5	1.25	23.5	23.5	0.99

Table 3. D50 (mm) value for peanut and carrot before and after orthetic treatment. The boluses were expectorated after 15 chewing cycles

Food	D50 before treatment (mm)	D50 after treatment (mm)
Peanut	9.16	7.62
Carrot	10.18	8.54

Evaluation of the result of the mastication process by granulometry analyses showed an improvement of the median particle size (D50) of the expectorated bolus after fitting with the orthetic device (table 3).

Evaluation via the modified Oral Assessment for Down Syndrome^{61,74} indicated that the majority of the items (13 out of 25) were improved by orthetic device wear, particularly chewing pieces of apple and pieces of meat, items for mandible and tongue posture, and acceptance of foods. The correction of dysmorphosis by an orthetic device succeeded in stabilizing the mandible by the increased number of ICUs. It allowed a more effective mastication as demonstrated by the improvement of all the chewing parameters, both video and granulometric. Also, with the help of the reeducation, it allowed safer swallowing with elimination of aspiration. In his parent's opinion, these functional results enabled our patient to have a normal life again, to be able to eat without fear in any context and to work again. His socialization was maintained and his quality of life, and that of his family, reached an acceptable level within the framework of his handicap.

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Chapter 11

Computer-Aided Oral Implant Surgery

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Abstract

In recent years, computer-aided oral implant surgery has been successfully implemented in routine clinical work. It integrates computed tomographic imaging, computerized implant planning and surgical guidance technology. Compared to conventional imaging, multi-slice computed tomography (MSCT) and recent cone-beam computed tomography (CBCT) allow for volumetric evaluation of the bony architecture. Curved multiplanary reconstructions (CMR), panoramic reconstructions (PR), and 3D volume rendering models (VR) are provided. Bone quality can be estimated based on measurement of Hounsfield Units (HU). For prosthetic-driven implant placement, individualized radiographic scan-templates are used. Oral implants are virtually planned on the computer with respect to anatomical and prosthodontic considerations. Compared to standard free hand drilling, surgical navigation systems are used for active instrument tracking based on the presurgical plan. Passive guidance systems use surgical templates manufactured via computer linked mechanical positioners or rapid prototyping. With both approaches successful standard open flap implant surgery, as well as minimal-invasive, transgingival (flapless) surgery, application of early / immediate loading concepts and positioning of zygoma implants have been published.

The present article reviews presurgical imaging, radiographic scan templates, computerized implant planning, different active and passive guidance technology, aspects of accuracy, clinical results, problems and future perspectives of computer-aided oral implant surgery.

Introduction

Implant supported oral restoration is an increasingly used treatment option for edentulous and partially edentulous patients. Successful prosthodontic rehabilitation of the patient in terms of esthetics, soft tissue aspects and osseointegration depends on careful study of the final prosthodontic goal, correct radiographic evaluation of available bone, careful planning of the implant positions and accurate surgical realization of the predefined plan [Dula et al. 2001; Jacobs 2000; Nemcovsky et al. 2000; Szmukler-Moncler et al. 2000; Andersen et al. 2002; Lorenzoni et al. 2003]. Edentulous ridge anatomy is often deficient in volume, which forces the surgeon to operate close to critical areas, such as the inferior alveolar nerve and sinuses. Violation of these critical areas can lead to permanent sensory loss, infection, or implant failure. Historically, oral surgeons tended to place implants where the greatest amount of bone was present, with less regard to placement of the definitive restoration. However, disregarding prosthetic demands often leads to a compromised definitive prosthesis with a jeopardized occlusal scheme, poor esthetics, or unfavorable biomechanics [Kopp et al. 2003; Rangert et al. 1995; Hobkirk et al. 1998; Stanford 1999]. Thus prosthodontic-driven implant placement has been implemented as a gold standard that combines functional and esthetic concepts [Becker and Kaiser 2000; Almog et al. 2001].

In the conventional approach, dental panoramic tomography and plain film tomography are used for radiographic evaluation. A radiographic scan template with integrated metal spheres at the position of the waxup is used for prosthetic-driven implant planning and estimation of the dimensions of the implants. However, standard radiography is prone to expansion and distortion, setting error, and position artefacts. There is no information of the bucco-oral dimensions and important anatomical variations such as mandibles with a lingual concavity are missed. Conventional surgical guides are fabricated on the diagnostic cast based on the wax-up. However, as the exact 3D anatomy below the surface is not known, they may only give a rough orientation during surgery. Thus, when conventional implantation techniques are used, the clinical outcome may often be unpredictable and the treatment is strongly dependent on the surgeon's experience and skills.

The implementation of computer-aided approaches has been dedicated to overcome the limitations with conventional techniques in order to improve the predictability of functional and esthetic results, and to enhance surgical confidence and patient safety [Gaggl et al. 2001; Sießegger et al. 2001; Sarment et al. 2003a; van Steenberghe et al. 2003; Vrielinck et al. 2003; Ewers et al. 2004; Ganz 2005; Widmann and Bale 2006]. The novel approach includes computed tomographic imaging, computerized prosthodontic driven implant planning and surgical guidance technology.

Presurgical Imaging

In computer-aided implant surgery, presurgical imaging is based on multi slice computed tomographic (MSCT) imaging or cone-beam computed tomographic (CBCT) imaging. MSCT uses a helically rotating x-ray source which is detected by an array of up to 64 detectors. To minimize metallic artifacts from metal crowns and bridgework within the

interested bone region, the patient's maxilla is horizontally positioned to the hard palate and the mandible is horizontally positioned to the alveolar crest, respectively [Dula et al. 1994; Frederiksen et al. 1995; Lenglinger et al. 1999]. CBCT enables to acquire 3D volume data in one rotation using a cone-shaped x-ray beam [Arai et al. 1999; Mozzo et al. 1998; Garg 2007; Sato et al. 2004]. Compared to MSCT such technology allows for a less expensive, smaller machine that exposes the patient to approximately 20% of the radiation of a MSCT [Queresby et al. 2008; Hashimoto et al. 2003; Mah et al. 2004; Palomo et al. 2006; Sukovic et al. 2001; Hatcher et al. 2003; Loubele et al. 2008c]. Disadvantages of CBCT are the scattered radiation, the limited dynamic range of the x-ray area detectors, the truncated view artifacts, and artifacts caused by beam hardening [Loubele et al. 2006; Mozzo et al. 1998; Endo et al. 2001; Hsieh et al. 2000; Katsumata et al. 2006; Mischkowski et al. 2007].

MDCT and CBCT allow for a complete 3D evaluation of the boney architecture [Rothmann et al. 1988; Vaughan 1996; Vannier et al. 1997; Preda et al. 1997; Lenglinger et al. 1999; Jacobs et al. 1999a, 1999b; Hassfeld and Stein 2000; Parks 2000; Kawamata et al. 2000; Dula et al. 2001; Abrahams 2001; Iplikcioglu et al. 2002; Garg 2007; Sato et al. 2004]. Cortical bone, trabecular matrix, the maxillary sinus, the inferior alveolar nerve, the mental foramen and important anatomical variations are excellently depicted.

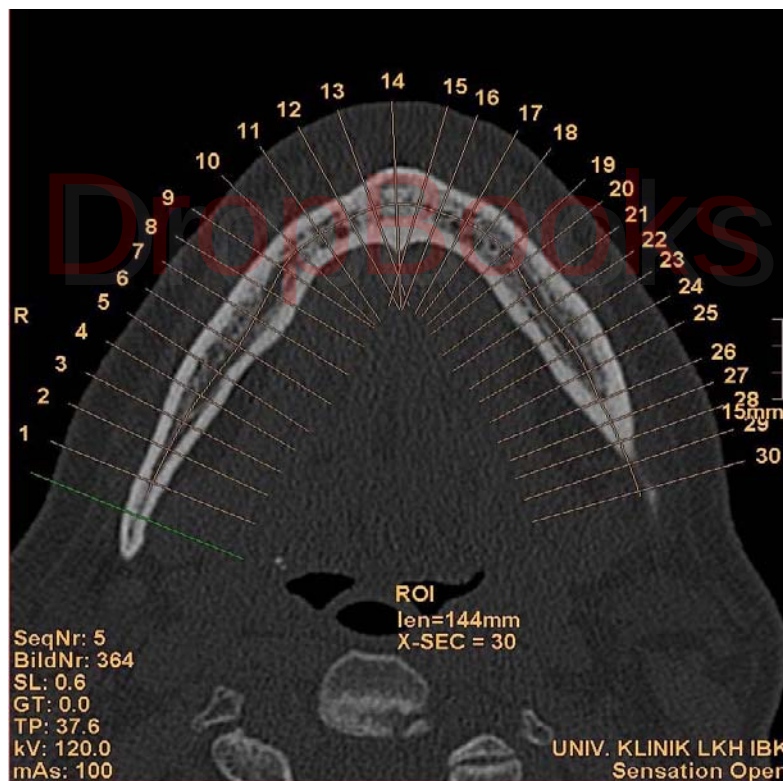


Figure 1. MDCT of the lower jaw, part 1. Definition of a user related curved cutting plane for curved multiplanary reformation (CPR) of cross sectionals and panoramic reconstructions. J-Vision Diag Beta 3D (GWI AG, Bonn, Germany).

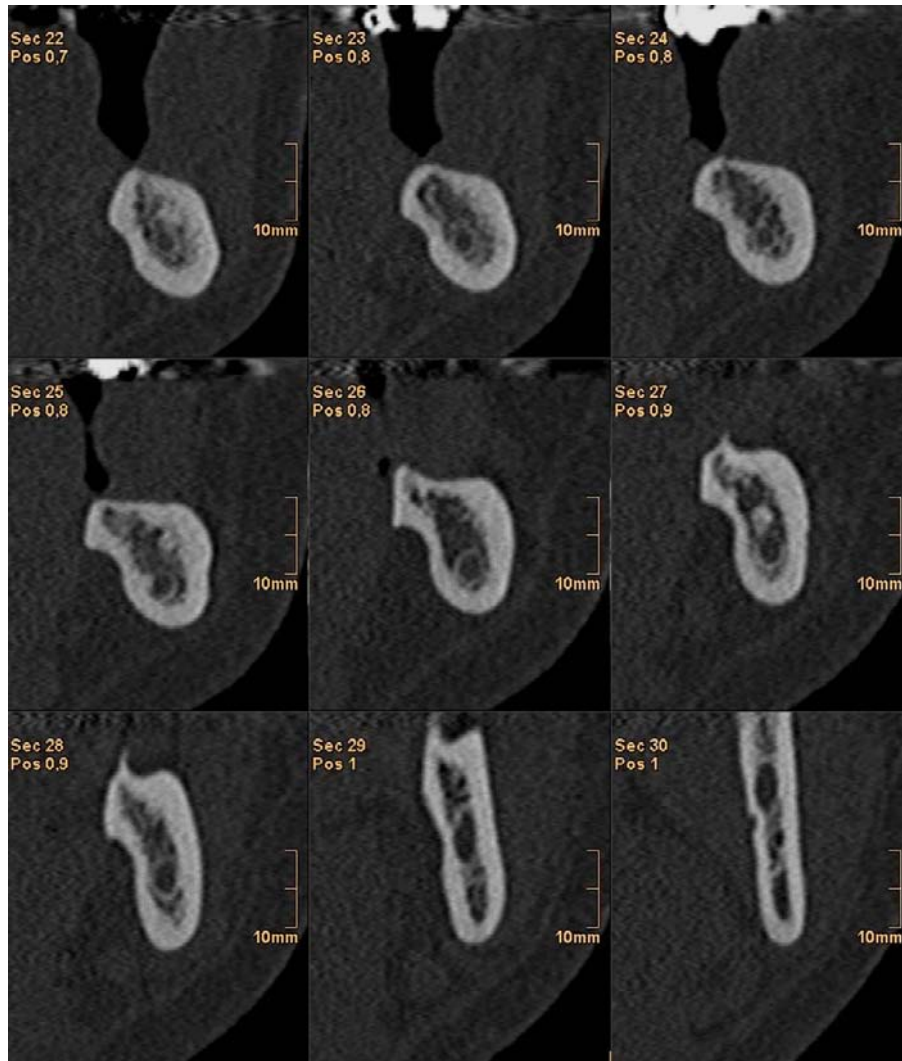


Figure 2. MDCT of the lower jaw, part 2. CPR cross-sectional view along the lower jaw which can be moved at any position along the curved plane in Figure 1. The cross sectionals clearly indicate the individual bucco-oral dimension and the relation to the mandible nerve. J-Vision Diag Beta 3D (GWI AG, Bonn, Germany).

Sophisticated 2D reconstructions such as multi-planar reformation (MPR) with axial, coronal, sagittal and oblique cuts, and curved-planar reformation (CPR) with cross sectionals and panoramic views related to any user defined curved cutting plane along the alveolar crest are provided [Schwarz et al. 1987a, 1987b; Rothman et al. 1988; Frederiksen et al. 1995; Besimo et al. 1995; Jacobs et al. 1999a; Solar and Gahleitner 1999; Parel and Triplett 2004] (Figure 1-3).

Volume rendering technology (VRT) allows for a complete 3D visualization and selective coloring of the mandibular channel or maxillary sinus [Reddy et al. 1994; Vaughan 1996; Kornas et al. 1998; Jacobs et al. 1999b; Solar et al. 2000; Kawamata et al. 2000; Bou Serhal et al. 2000; Dula et al. 2001; Cavalcanti et al. 2002; Gray et al. 2003] (Figure 4).

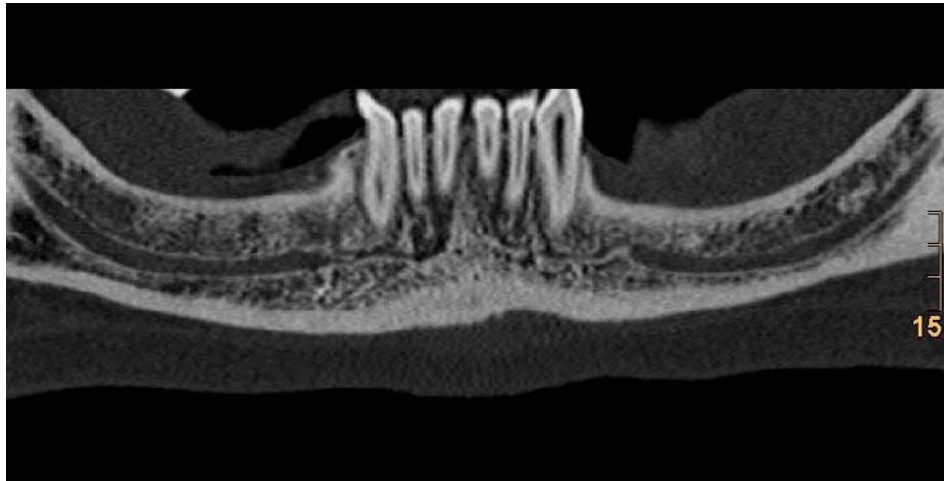


Figure 3. MDCT of the lower jaw, part 3. CPR panoramic reconstruction based on the user related curved plane in Figure 1. The superior-inferior and right-left plane can be varied along the central horizontal and vertical plane. J-Vision Diag Beta 3D (GWI AG, Bonn, Germany).

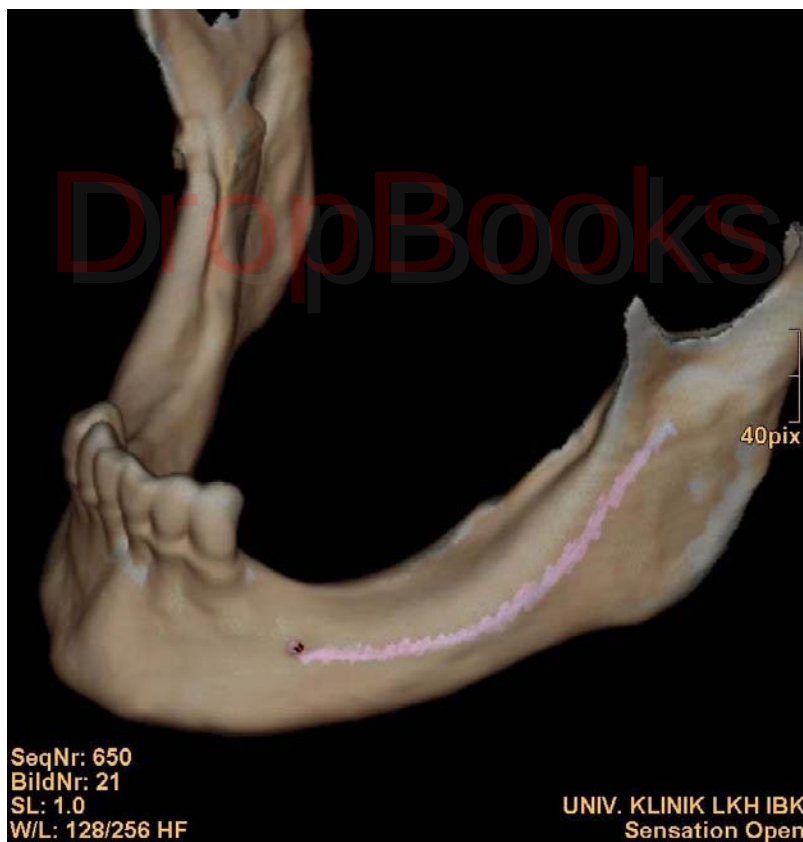


Figure 4. MDCT of the lower jaw, part 4. 3D volume rendering technique (VRT) with colored segmentation of the mandible nerve. Advanced Workstation 4.2 (GE Healthcare, Chalfont St. Giles, United Kingdom).

Beside morphologic imaging, MSCT can be used for a standardized estimation of bone quality based on measurement of Hounsfield Units (HU) (-1000 air, 0 water, +1000 cortical bone).

Radiographic Scan Template

The aim of a radiographic scan template is to visualize the proposed prosthodontic reconstruction on the image data for prosthetic-guided oral implant planning (backward planning, or crown down planning) [Pesun and Gardner 1995; Takeshita and Suetsugu 1996; Becker and Kaiser 2000; Wat et al. 2002; Siu et al. 2003]. The individualized scan-template is based on a resin splint which exactly fits to the remaining teeth (Figure 5).

A stiff occlusal index or contralateral record in centric occlusion is used for stabilization of the opposing dentition during the scan procedure [Parel and Triplett 2004]. The following radiographic markers can be integrated: gutta percha balls and stripes [Ku et al. 2000; Almog et al. 2001; Parel and Triplett 2004], metal pins and tubes [Cehreli et al. 2000, Cehreli and Sahin 2000; Solow et al. 2001; Ganz 2005], radiopaque varnishes [Basten 1995; Siu et al. 2003], lead foil [Adrian et al. 1992; Urquiola et al. 1997] or prefabricated radiopaque teeth [Sundbrink 2005]. In fully edentulous patients, the prosthesis of the patient may be used as a radiographic guide [van Steenberghe et al. 2002; Parel and Triplett 2004].



Figure 5. Radiographic scan template. Radiopaque markers are integrated in a resin template at the position of the proposed prosthodontic reconstruction for visualization in the CT-data for prosthetic-guided oral implant planning (backward planning, or crown down planning).

The radiographic template is usually integrated into the registration template, used for fixation of the dynamic reference frame, or converted to a surgical template.

Computerized Implant Planning

Following the pioneering work of Verstreken et al. implants are virtually planned on the patient's CT-data on the computer [Verstreken et al. 1996, 1998]. Using intuitive drag and drop tools, location, angle, depth and diameter of implants are virtually planned on the patient's CT-data based on MPR, CPR, panoramic reconstructions and 3D-VRT with respect to the prosthetic goal, bone morphology and delicate anatomic structures [Takeshita and Suetsugu 1996; Verstreken et al. 1996, 1998; Ganz 2005; van Steenberghe et al. 2005; Sanna et al. 2007] (Figure 6, 7).

Implant libraries allow a precise 1:1 projection of commercially available implant types (Figure 8). Sophisticated software can automatically calculate the bone density within and near to the proposed implant site.

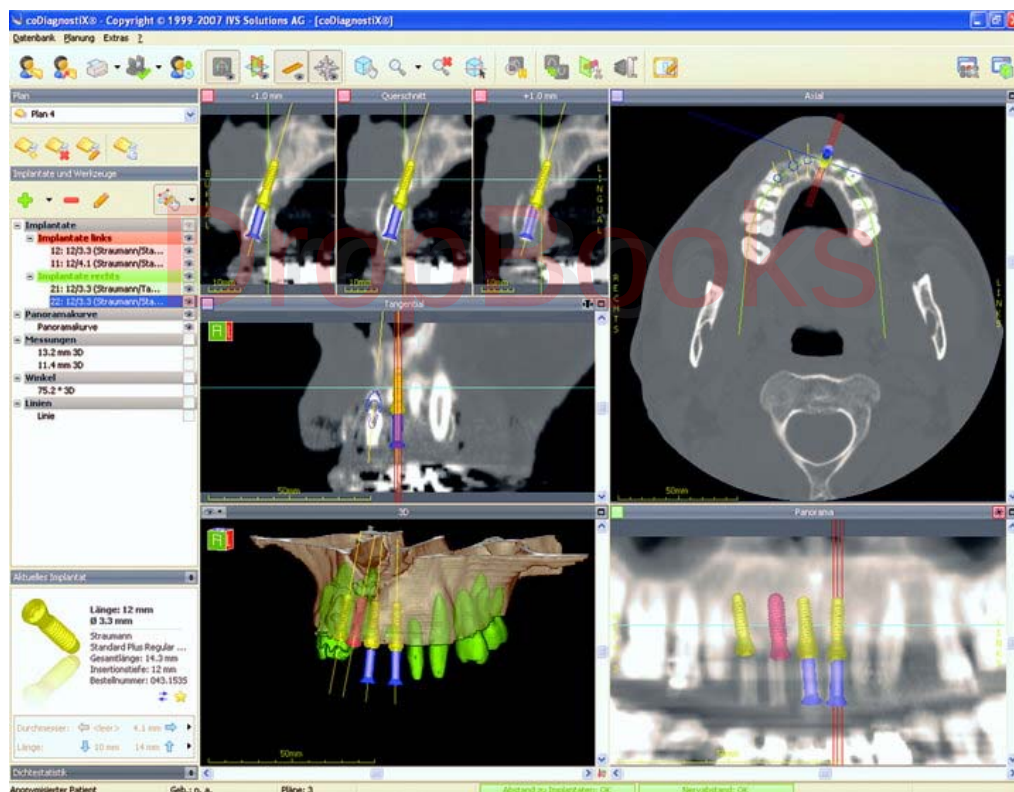


Figure 6. Computerized implant planning in the maxilla. CPR (cross-sectionals, upper left, and panoramic reconstructions (lower right), MPR (middle left and upper right), and 3D-VRT (lower left). Courtesy of IVS Solutions (coDiagnostiX, IVS Solutions AG, Chemnitz, Germany).

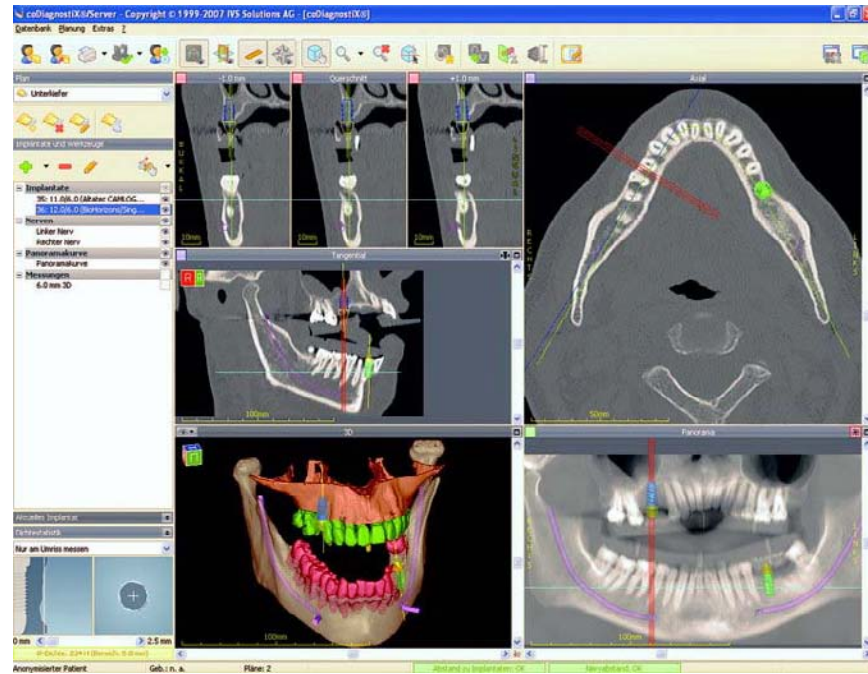


Figure 7. Computerized implant planning in the mandible. CPR (cross-sectionals, upper left, and panoramic reconstructions (lower right), MPR (middle left and upper right), and 3D-VRT (lower left). Courtesy of IVS Solutions (coDiagnostiX, IVS Solutions AG, Chemnitz, Germany).

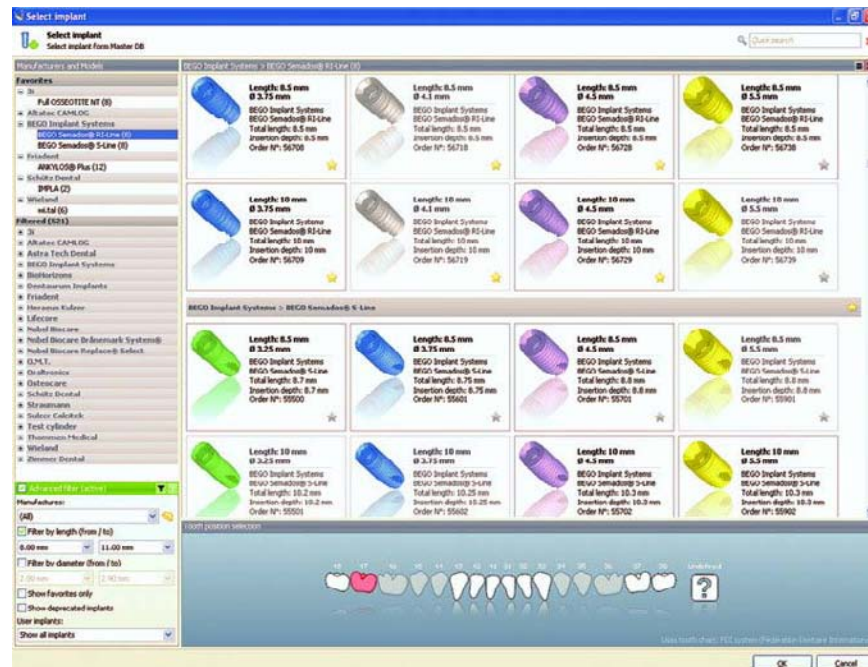


Figure 8. Implant libraries allow a precise 1:1 projection of commercially available implant types. Courtesy of IVS Solutions (coDiagnostiX, IVS Solutions AG, Chemnitz, Germany).

Examples of planning software are (alphabetic order):

- Artma Virtual Implant [Artma Medical Technologies AG, Vienna, Austria]
- coDiagnostiX [IVS Solutions AG, Chemnitz, Germany]
- DenX's IGI [DenX Ltd, Jerusalem, Israel]
- Easy Guide [Keystone-dental, Burlington, MA, USA]
- Implant Logics [Implant Logic systems Ltd., Cedarhurst, NY, USA]
- ImplantMaster [iDent, Ft. Lauderdale, Florida, USA]
- Med3D [Med3D GmbH, Heidelberg, Germany]
- NaviGuide System RoboDent [RoboDent GmbH, Berlin, Germany]
- Procera [Nobel Biocare, Göteborg, Sweden]
- SimPlant [Materialise Medical Inc., Leuven, Belgium].

Active Image-Guidance: Surgical Navigation

Surgical navigation systems have been initially developed for neurosurgery to replace cumbersome frame based stereotaxy. The novel technology assists the surgeon by interactive integration of three fundamental components: localization, orientation, and navigation [Grunert et al. 2003; Wagner et al. 2003; Meyer et al. 2003; Casap et al 2004, 2005b; Kramer et al. 2004; Ewers et al. 2004, 2005; Wittwer et al. 2006; 2007a, 2007b, 2007c]. Localization defines a task where the surgeon has to go, orientation refers to information on current location that defines where the surgical tool is now related to the patient's anatomy, and navigation is the process of guidance to reach a desired target from the current location, or how to get from here to there [Grunert et al. 2003]. Navigation systems are composed of a transportable workstation, a high-resolution display, a graphical user interface and several software applications, a position measuring system, and various probes or tracking adapters which can be mounted to surgical tools (Figure 9). The guidance system or position measuring system (PMS) of standard optical based navigation systems works similar to that of the global positioning system (GPS) in cars: Similar to the satellite, a stereoscopic camera detects LED's (light emitting diodes) or passive reflecting tracking elements, which are mounted to a dynamic reference frame (DRF) on the patient, and to the surgical tools and calculates the position of the surgical tool in relation to the DRF (Figure 10-12).

Examples of navigation systems used for oral implant surgery are (alphabetic order):

- Artma [Artma Medical Technologies AG, Vienna, Austria]
- DenX IGI [DenX Ltd, Jerusalem, Israel]
- RoboDent [RoboDent GmbH, Garching b. München, Germany]
- StealthStation Treon plus [Medtronic Inc., Louisville, USA]
- VoNaviX CMF [IVS Solutions AG, Chemnitz, Germany].



Figure 9. Surgical navigation system. The components include a transportable workstation, a high-resolution display, a graphical user interface and several software applications, and an optical based position measuring system with a stereoscopic camera. Courtesy of IVS Solutions (VoNaviX CMF, IVS Solutions AG, Chemnitz, Germany).



Figure 10. Dynamic reference frame (DRF). Tracking elements such as passive light reflecting glass balls are mounted to a frame which is connected to the registration template. The DRF provides the reference coordinate system for the navigation system. Courtesy of RoboDent (RoboDent GmbH, Garching b. München, Germany).



Figure 11. Tracked surgical drill. An adapter with tracking elements is mounted to the surgical tool for detection by the stereoscopic camera. Courtesy of RoboDent (RoboDent GmbH, Garching b. München, Germany).

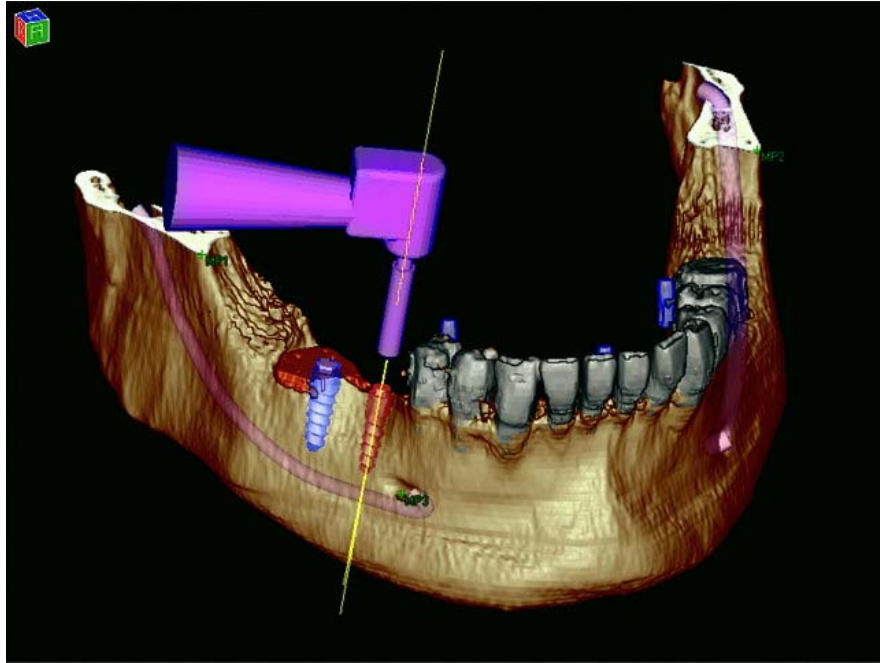


Figure 12. Surgical tool tracking. The position of the tracked surgical tool is recorded in real-time and projected onto the patients presurgical CT-data with the predefined surgical plan. Courtesy of IVS Solutions (VoNaviX CMF, IVS Solutions AG, Chemnitz, Germany).

Registration

As a prerequisite to navigation, the physical space coordinates of the patient have to be linked to the patient's image coordinates, a process called registration. The most widely used registration method is the paired-point rigid body coordinate transformation: The coordinates of corresponding points (fiducials) in the image (manually or semi-automatically defined on the computer) and on the patient (with the probe of the navigation system) are determined and the geometrical transformation that best aligns these points is computed [Gumprecht et al. 1999; Germano et al. 1999; Grunert et al. 2003; Alp et al. 1998; Hassfeld and Muehling 2001; Bale et al. 2000a, 2001; Schultes et al. 2001; Wolfsberger et al. 2002; Widmann et al. 2005; Klug et al. 2006]. Registration can be provided via implanted bone markers, noninvasive registration templates or an external registration frame [Eggers et al. 2006; Ewers et al. 2004; Mischkowski et al. 2007; Widmann 2007; Widmann 2006, 2007]. Use of anatomical landmarks, skin fiducials and surface registration showed unsatisfactory accuracy for navigated oral implant surgery [Mischowski et al. 2007].

Bone markers generally consist of micro bone screws which are anchored to the patient's alveolar process [Wittwer et al. 2007a, 2007c, 2006; Eggers et al. 2006]. As an advantage these markers are rigidly implanted and thus not susceptible to shifts or loosening. They are considered to provide the highest accuracy and represent the gold standard. A drawback is that they are invasive, need additional surgery and may include patient discomfort for which they should not be left in place for an extended period [Bale et al. 2000a; Edwards et al.

2000; Marmulla et al. 2004c]. The DRF of the navigation system has to be invasively secured to the jaw bone [Wagner et al. 2003a; Wanschitz et al. 2002b; 2002a; Wittwer et al. 2007a, 2007c, 2006].

Registration templates are denture fixed acrylic templates with integrated fiducial markers [Edwards et al. 2000; Schmelzeisen et al. 2002; Kniha et al. 2003; Meyer et al. 2003; Schultes et al. 2003; Casap et al. 2004; Neugebauer et al. 2004; Blanchet et al. 2004; Kramer et al. 2005; Eggers et al. 2005a, 2005b; Klug et al. 2006]. Usually the registration template is integrated in the radiographic scan template and supplied with the opposing dentition for stable fixation during imaging. The registration template is completely non-invasive and can be simultaneously used for fixation of the DRF of the navigation system [Casap et al. 2006] (Figure 10). As a drawback, registration templates require a dental laboratory specialist and additional time and costs to fabricate the individualized templates in the laboratory. In edentulous patients the resilience of the oral mucosa precludes stable and invariant positioning which may only be managed by securing the template to the underlying bone, e.g. via a fixed reference system [Casap et al. 2005b].

External registration frames are jaw surrounding constructions with fiducials [Widmann et al. 2005, 2007, 2009a; Bale et al. 2000] (Figure 13). Compared to registration templates which only allow for small markers and limited geometric marker distribution within the oral cavity, external frames can provide large markers with broad distribution around the jaw. For the registration process reference markers with a central pivot that exactly correspond to the center of the imaging markers facilitate probe placement.

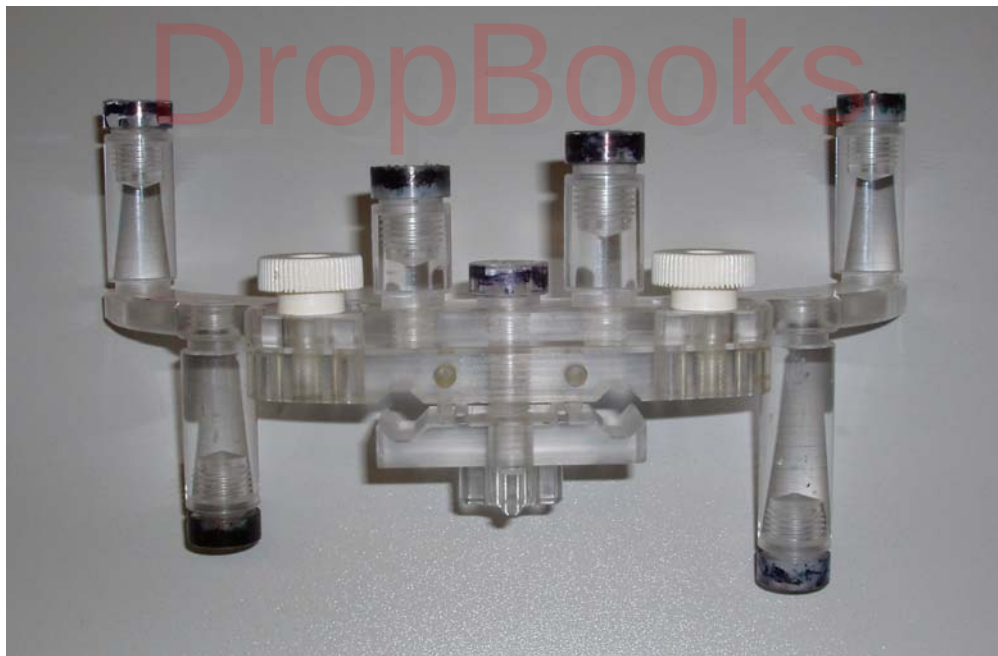


Figure 13. External registration frame. 7 registration markers are broadly distributed around the C-shaped frame. For the registration process with the probe of a navigation system, reference markers with a central pivot that exactly correspond to the center of the imaging markers are used.

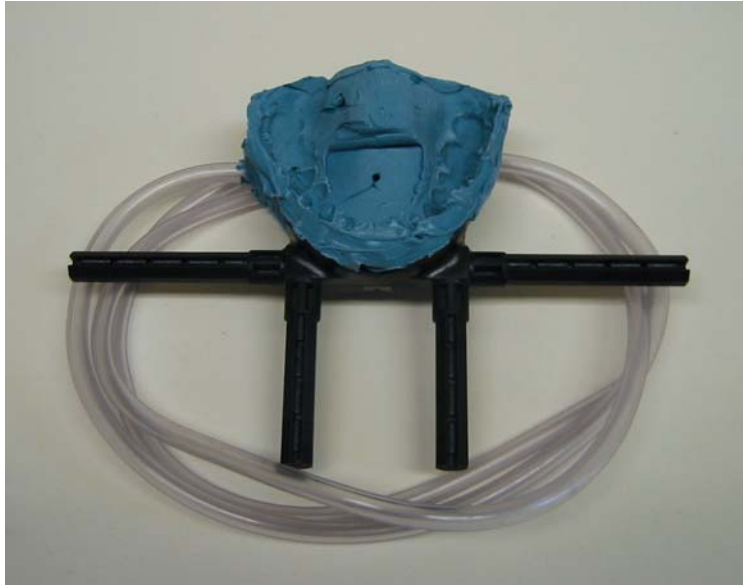


Figure 14. Vogele-Bale-Hohner (VBH) vacuum mouthpiece. The mouthpiece is only provided with the patient's dental impression (Medical Intelligence GmbH, Schwabmuenchen, Germany). The vacuum objectively secures the mouthpiece against the maxilla and provides submillimetric repositioning control.



Figure 15. Modified VBH mouthpiece. A radiographic scan template is directly glued to a modified VBH mouthpiece. The contralateral record in centric occlusion is used for stabilization of the opposing dentition during the scan procedure.

The frame has to be connected to a template, such as the VBH mouthpiece and is removed after the registration procedure (Figure 14). In contrast to resin templates the VBH vacuum mouthpiece may only be provided with the patient's dental impression [Widmann et al. 2005, 2007, Martin et al. 1998]. The vacuum objectively secures the mouthpiece against the maxilla and provides submillimetric repositioning control, which is regulated by the amount of negative pressure on the vacuum scale of the pump [Martin et al. 1998; Bale et al. 2000; Sweeney et al. 2001, 2003]. For implant surgery in the mandible, the additional impression of the mandible is obtained using the stone casts and the dental articulator. Alternatively, a modified VBH mouthpiece can be directly glued to a radiographic scan template (Figure 15).

Active Guidance (Navigation)

After registration, the navigation system is ready for surgical use. The DRF (invasively secured to the bone or non-invasively secured to the remaining teeth via a resin template) is in constant relationship to the registered patient and even if the patient's head moves, the system can compensate for such movement, thus avoiding the need to re-perform calibration [Wittwer et al. 2007b; Casap et al. 2005a, 2005b]. Surgical navigation is an active-guided procedure. The position of the tracked surgical tool is recorded in real-time and projected onto the patients presurgical CT-data. During navigation, continuous visual contact between the camera and the tracking elements on the DRF and surgical drill has to be warranted. The surgeon can guide the drill along the planned path as visualized on the computer screen or head mounted devices and the navigation software indicates the accuracy of the drill's position and angulations [Wittwer et al. 2007b; Wanschitz et al. 2002a]. Special guidance views help to find the planned implant location and to follow the surgical path into the bone [Wittwer et al. 2007b; Casap et al. 2005a; Mischowski et al. 2006]. Changes of the surgical plan can be made intraoperatively.

Passive Image-Guidance: CT-Guided Surgical Templates

Passive image-guidance is provided by surgical templates [Vercruyssen et al. 2008]. CT-guided surgical templates can be produced via mechanical positioning devices or drilling machines, stereolithography or via multi-purpose navigation systems. The surgical bur tubes are usually made of titanium and are adapted to the dimension of the surgical drill(s).

(1) Mechanical positioning devices or drilling machines are adjustable hexapod tables or tables which allow for several angular adjustments in order to place the patient's dental stone cast in relation to the surgical plan (Figure 16). The registration template (including e.g. a registration stone, metal tubes or pins) is recognized by the positioning device as a reference for the transfer algorithm. Based on the obtained specific numerical data for the positioning device, each surgical bur tube is individually positioned on the patient's dental stone cast and fixed into a customized surgical resin template [Braun 1999; Fortin et al. 2000, 2002; Struck

et al 2001; Mueller and Dotzauer 2002; Kopp et al. 2003] (Figure 17). Usually the radiographic / registration template is converted to the surgical template.



Figure 16. Mechanical positioning device for CT-guided surgical template production. Based on the obtained specific numerical data for the mechanical positioning device, each surgical bur tube is individually positioned on the patient's dental stone cast and fixed into a surgical template. Courtesy of IVS Solutions (gonyX, IVS Solutions AG, Chemnitz, Germany).



Figure 17. CT-guided surgical template on the dental stone cast with titanium surgical bur tubes. Courtesy of IVS Solutions (gonyX, IVS Solutions AG, Chemnitz, Germany).

Examples of CT-guided templates via mechanical positioning devices or drilling machines are (alphabetic order):

- 3D-finder [Praxis Systemtechnik GbR, Besigheim, Germany]
- gonyX [IVS Solutions AG, Chemnitz, Germany]
- X1med3D [Georg Schick Dental GmbH, Schemmerhofen, Germany].

(2) Computer-aided design (CAD) / computer-aided manufacturing (CAM) can be used to produce surgical templates via rapid prototyping technology, a laser-dependent stereolithographic polymerization process. For the registration a double scan technique based on a registration template with 6 to 8 reference markers is used [Verstreken et al. 1996, 1998]. Both the patient with registration template and the registration template alone are scanned with the same scan-parameters. The two datasets are subsequently fused on the basis of the markers. Tooth, mucosa, or bone supported templates can be fabricated [Santler et al. 1998; Vrielinck et al. 2003; Sarment et al. 2003a, 2003b; Tardieu et al. 2003; Parel and Triplett 2004; Sammartino et al. 2004; Sudbrink 2005; Ganz 2005] (Figure 18, 19).



Figure 18. Tooth supported CAD/CAM rapid prototyping stereolithographic template. Courtesy of Materialise Medical (SurgiGuide, Materialise Medical Inc., Leuven, Belgium).

Compared to positioning devices which require fixing each bur tube separately, one after the other, stereolithographic templates are manufactured at a one stage procedure.

Examples of CT-guided templates via stereolithography are (alphabetic order):

- iGuide [iDent, Ft. Lauderdale, Florida, USA]
- NobelGuide [Nobel Biocare, Göteborg, Sweden]
- SurgiGuide [Materialise Medical Inc., Leuven, Belgium].



Figure 19. Bone supported CAD/CAM rapid prototyping stereolithographic templates with the stereolithographic bone model. Courtesy of Materialise Medical (SurgiGuide, Materialise Medical Inc., Leuven, Belgium).

(3) In a different rapid prototyping approach, special guidance sheaths are placed into an electromechanical device and automatically formed according to the computer-based surgical plan [Schicho et al. 2007; Tal et al. 2007]. Then the sheaths are cured by means of ultraviolet (UV) light flashes. As the guidance sheaths are disposable, the approach may allow for an easy intraoperative modification of the plan. The preformed guidance sheaths are attached either to the registration template or a bone surface imaging needle array (BSINA). The registration template consists of a standardized plate with several registration markers. The BSINA is a bone anchored micromechatronic device which consists of an array of cartridges with micro-needles that are pushed through the patient's gingival until they touch the bone surface [Schicho et al. 2007]. An encoder continuously measures the piston displacement and a local bone surface mapping is provided. The medical impression image is then aligned with the surface reconstruction of the patient's CT-data. As an advantage, CT-scans can be used without obligatory registration template; as a drawback the procedure is invasive.

This rapid prototyping approach is provided by:

- Implant Location System (ILS) [Tactile Technologies Ltd., Rehovot, Israel].

(4) Computer-aided surgical templates may also be produced using a multi-purpose surgical navigation system such as are already installed in many departments (neurosurgery, orthopaedics, ENT, cranio-maxillo-facial surgery) of bigger hospitals. Instead on the patient, the navigation procedure is performed on the patient's registered dental stone cast in the laboratory [Widmann et al. 2005, 2007, 2009a] (Figure 20). The VBH mouthpiece with the external registration frame is the favourite registration method [Widmann et al. 2005, 2009]. The DRF can be easily mounted to the base plate of the laboratory set-up and need not to be fixed to the patient via template or invasively to the bone. A radiographic scan template may not be necessary because the wax-up can be indicated with the navigation probe on the dental stone cast. The aiming device helps for trajectory alignment at the best technical level. There is no intraoperative line of sight constraint and no influence on the surgeon's ability to transfer the navigational data via hand-moved tracked surgical drill.

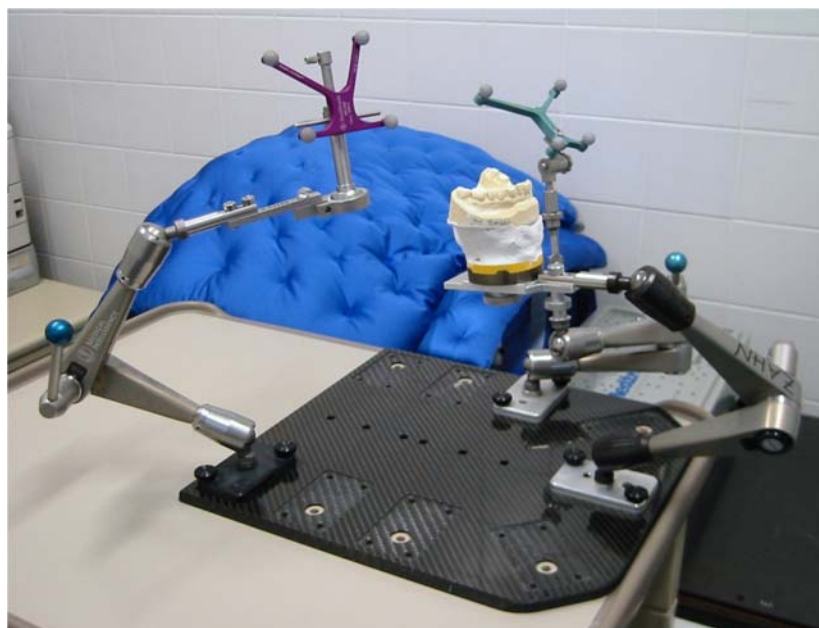


Figure 20. CT-guided template fabrication using a navigation system. Laboratory set-up consisting of a base plate with multiple fixation areas for the mechanical arms, mechanical arm holding the unmodified dental stone cast of the patient (right), DRF of the navigation system (background) (StealthStation Treon plus, Medtronic Inc., Louisville, USA), and the EasyGuide aiming device (left).



Figure 21. CT-guided template fabrication using a navigation system. Method 1. The aiming device of the navigation system is used for direct positioning of surgical bur tubes on the dental stone casts. One by one, the bur tubes are affixed into a prefabricated template with blue light-curing resin.

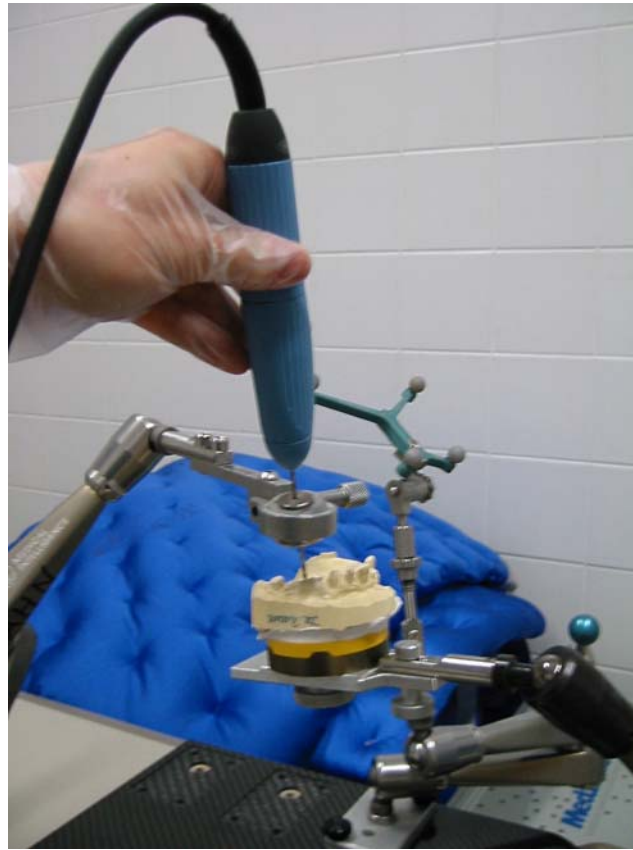


Figure 22. CT-guided template fabrication using a navigation system. Method 2. The aiming device of the navigation system is used to guide drillings into the dental stone casts, and the surgical bur tubes are indirectly positioned by metal rods inserted in the drill holes. The bur tubes are affixed in the surgical template in a single session in the dental laboratory.

In method 1, the bur tube is positioned on the dental stone casts by a metal rod advanced through the adjusted aiming device. One by one the bur tubes are then polymerized into a prefabricated resin template using an ultraviolet (UV) light-curing resin (Figure 21). In method 2, the aiming device is used to guide drillings into the casts (Figure 22). Metal rods are inserted into the drill holes and used to position surgical bur tubes. The bur tubes are fixed into a resin template in a single session in the dental laboratory. Compared to method 1, method 2 requires less effort and allows for faster completion in a single session [Widmann et al. 2007]. Based on this technique, an institution may successfully provide both, intraoperative surgical navigation (for oral implant surgery, CMF, ENT surgery, etc.) and CT-guided surgical templates (serving internal and external oral surgeons).

Passive Guidance

Passive guidance does not require an intraoperative registration procedure. During surgery the surgical template is integrated in the mouth of the patient and is hold by the

remaining teeth. For appropriate use in edentulous patients or in extensive distal free-end situations, the surgical template needs to be secured to the underlying bone stabilizing pins fixed in occlusion [Simon 2002; Fortin et al. 2003, 2006; Tardieu et al. 2003; Blanchet et al. 2004; Parel and Triplett 2004; Valente et al. 2006; van Steenberghe et al. 2004, 2005; Sanna et al. 2007; Van Assche et al. 2007]. Usually the pilot drill is guided by the template. In order to guide the subsequent surgical drillings, several subsequent surgical templates or removable drill guides with varying diameter can be used. Depth control during surgery is performed by drill stops.

Aspects of Accuracy

The overall accuracy of computer-aided implant surgery includes all possible single errors from the image acquisition to the surgical implant positioning in a cumulative and interactive manner [Fortin et al. 2002; Casap et al. 2004; Widmann and Bale 2006; Widmann et al. 2009b]. By principle, technical error, imaging error, registration error, and application error can be differentiated. It is noteworthy that man made (human) errors contribute to all machine made errors [Spetzger et al. 2002; Widmann and Bale 2006; Widmann et al. 2009b].

Technical error refers to the inherent hard and software error of the computer-aided position measuring system in surgical navigation, or the error of the mechanical positioning device or rapid prototyping technology in template based systems. (1) Optical based surgical navigation systems offer a position measuring accuracy in the range of 0.1 – 0.4 mm [Khadem et al. 2000]. Temporal variation in positioning recording, called “jitter” is caused by factors such as thermal noise and can be approximately 20%-40% of total localization error [West and Maurer 2004]. The optical center of the tracking elements is slightly angle dependent, and errors may become substantial for angles higher than 60°. Correct positioning of tracking elements, DRF and the optical position sensor (stereoscopic camera) at correct distance to each other is important to minimize localization error [West and Maurer 2004]. (2) With mechanical positioning devices or drilling machines, technical errors are considered to be neglectable. Stereolithography allows for a technical accuracy of 0.1 and 0.2 mm [van Steenberghe et al. 2002]. It is essential that the bur tubes are perfectly adapted to the dimensions of the surgical drill. Angular deviations will lead to large errors along the drill distance.

Imaging error is the error of the imaging modality in geometrically correct depicting of anatomical structures. Latest MSCT and CBCT technology show submillimeter accuracy for linear measurements reaching the level of the image resolution [Cavalcanti et al. 2002; Loubele et al. 2008a]. It is important to exclude patient motion during preoperative scanning which may account for translation movements of a maximum of 0.5 cm and rotations of more than 2° without perceptible motion artefacts [Wagner et al. 2003].

Registration error is the error of the spatial linkage of the patient's body and the image data of this individual anatomy. The registration accuracy is responsible for accurate linking of the virtual planning to the surgical site and has been shown to be the most influential part in computer-aided surgery. In point-based registration, use of more than four registration markers is recommended (although the return diminishes rapidly after five or six markers are

used) and the markers should be arranged in a spreaded setting around the target volume [West et al. 2001; Abbasi et al. MICCAI 2000; Fitzpatrick et al. 1998; Eggers et al. 2006; West et al. 2001]. Compared to invasive marker registration, the registration template or external registration frame may provide similar registration accuracy. However, different to invasive markers, registration templates require a repositioning procedure and thus may loose or misfit. Perfect dental impressions and dental stone casts are a prerequisite for templates with proper fit and high repositioning accuracy. Proper fit during imaging and registration has to be verified and before surgery the registration accuracy has to be checked. [Hoffmann et al. 2005; Birkfellner et al. 2001; Casap et al. 2004; Eggers et al. 2005b; Widmann et al. 2005, 2007]. This can be performed by using anatomical checkpoints on the patient which are touched with a navigation probe or the tracked surgical drill. In passive systems, a control chart may rule out errors.

Application error refers to the error of the active or passive guided surgical tool during the actual surgical procedure and further refers to the accuracy of the achieved surgical result compared to the initial plan. (1) In surgical navigation, the drill is still manually moved by the surgeon, and not rigidly guided such as in a surgical template [Ruppin et al. 2008]. Unfavorable geometry of the alveolar process with concave plate and bony edge may lead to an eccentric shift during implant bed preparation [Wittwer et al. 2006]. Loosening of the DRF is to be avoided and when the camera position has to be changed due to line-of-sight problems it must be placed at the correct distance and angle. (2) In surgical templates, a crucial factor is the stability and inherent support of the template [Assche et al. 2008]. This support is less provided in partial edentulous with large free-end situation and definitely poor in edentulous patients. In these cases proper placement of stabilizing pins fixed in occlusion is required [Simon 2002; Fortin et al. 2003, 2006; Tardieu et al. 2003; Blanchet et al. 2004; Parel and Triplett 2004; Valente et al. 2006; van Steenberghe et al. 2004, 2005; Sanna et al. 2007]. Bending of the template during surgery has to be avoided. Template resin material is waterabsorbable and heat sensitive and therefore may undergo some deformation during time [Nikzad and Azari 2008].

It is important to note that the accuracy of computer-aided surgery including both, active and passive approaches may reach non-acceptable levels and should not be trusted for blind. Knowledge on errors and their contribution to the overall accuracy is essential in order to understand the possibilities and limitations of this technology [Vercruyssen et al. 2008; Widmann and Bale 2006; Widmann et al. 2009b]. Appropriate strategies and error control mechanism have to be implemented to verify correct performance of each procedural step.

Clinical Results

(1) CT imaging overcomes the limitations of conventional imaging such as sensitivity to expansion and distortion factor, projection errors depending on patient positioning, possible misinterpretation of bone height, poor information on bone quality, and most important, missing information about the bucco-oral dimension [Batenburg et al. 1998; Jacobs 2000; Tepper et al. 2001; Iplikcioglu et al. 2002; Bou Serhal et al. 2002; Reddy et al. 1994; Wicht et al. 1994; Jacobs et al. 1999b; Kawamata et al. 2000; Dula et al. 2001]. This is reflected by

the fact that many clinical situations demand CT-examination for optimal preoperative implant planning, e.g. placement of a fixed prosthesis in the completely edentulous jaw, severe bone loss with enlarged incisor canal for single implants in the incisor region or multiple implants in the incisor and canine region [Dula et al. 1994, 1996, 2001; Schom et al. 1996; Iplikcioglu et al. 2002; Harris et al. 2002b; Bou Serhal et al. 2002]. Important anatomical variations of the nasopalatine canal [Mraiwa et al. 2004], existence of a mandibular incisive canal with a true neurovascular supply [Mraiwa et al. 2003] and mandibles with a lingual concavity or a severe slope of the lingual cortex [Quirynen 2003] can be detected to avoid any neurovascular complications up to life threatening floor of mouth hemorrhage [Kalpidis 2004; Woo et al. 2006]. With recent scan protocols, measurement accuracy reaches the image resolution of 0.1 – 0.4 mm. There are no significant differences in precision (reproducibility) or accuracy (validity) of 3D volume rendered images from MSCT data sets between either inter- or intraobserver measurements or between in vitro and in vivo measurements [Cavalcanti et al. 2002; Loubele et al. 2008a]. Comparing latest CBCT to MSCT, there are no significant differences between radiographic and direct linear measurements [Loubele et al. 2008; Lascala et al. 2004]. In terms of image quality, CBCT offers better visualization of details of the small bony structures while MSCT offers better visualization of the cortical bone and the gingival tissue [Hashimoto et al. 2006; Loubele et al. 2007, 2008b]. CBCT in conjunction with software that renders immediate treatment plans provides the most precise radiographic modality currently available for presurgical evaluation for oral implants [Garg 2007; Sato et al. 2004, Loubele et al. 2007]. In terms of bone quality assessment based on MDCT the following correlations between the bone quality after Lekholm and Zarb and bone density range in HU were found: Quality 1: >+850, Quality 2/3: +500 to +850, Quality 4: 0 to +500, and Quality 4*: <0 [Reddy et al. 1994; Kornas et al. 1998; Solar et al. 2000; Sießegger et al. 2001; Cavalcanti et al. 1998, 2002; Shapurian et al. 2006; Norton and Gamble 2001].

The clinical importance of these findings is confirmed in recent studies which show a statistically significant correlation between bone density measures in HU and implant stability parameters [Turkyilmaz et al. 2006, 2007a, 2007b; Homolka et al. 2002].

(2) Computer-aided implant planning combines the esthetic and functional advantages of prosthodontic-driven implant positioning [van Steenberghe et al. 2002; Tardieu et al. 2003; Ewers et al. 2004, 2005]. The available bone can be fully taken into consideration, which may allow for longer implants (and thus superior implant stability) and perhaps the omission of additional surgical effort such as bone grafting or sinus augmentation [Siessegger et al. 2001; Sarment et al. 2003a; Vrielinck et al. 2003].

(3) Compared to the conventional technique, computer-aided implant surgery seems to be superior on account of its potential to eliminate possible manual placement errors and to systematize reproducible treatment success. Comparative studies have shown significant higher accuracy with image guidance than with the conventional method [Schermeier et al. 2001; Sarment et al. 2003a; Kramer et al. 2004; Brief et al. 2005; Hoffmann et al. 2005a]. The accuracy of both methods, surgical navigation and CT-guided templates has proven to be sufficient for routine clinical practice [Besimo et al. 2000; Naitoh et al. 2000; van Steenberghe et al. 2002; Wanschitz et al. 2002a, 2002b; Wagner et al. 2003; Sarment et al. 2003; Brief et al. 2005; Hoffmann et al. 2005; Widmann and Bale 2006; Ruppert et al. 2008;

Vercruyssen et al. 2008; Widmann et al. 2009b]. A safety distance of about 1 mm up to the maximum error of the applied system is recommended for a reliable protection of critical anatomic structures [Gaggl et al. 2001; Schultes et al. 1999].

(4) Successful application of flapless surgery and early or immediate loading concepts have been described for both, active and passive guidance techniques [van Steenberghe et al. 2002; Fortin et al. 2004, 2006; Parel and Triplett 2005; Sudbrink 2005; Casap et al. 2005; Wittwer et al. 2007a, 2007c, 2006]. Flapless surgery is a “blind” procedure because the surgeon cannot directly see to the underlying bone and image-guidance proved to be very helpful in this approach. Immediate loading and early loading should indicate the provision of occlusal contact within a few days or after 1 or 2 weeks, respectively [van Steenberghe et al. 2002]. Due to the accurate transfer of planning to the study cast and to the surgical site the position of the implants corresponds well to the crown units of the provisional prosthesis. In addition, computer-aided surgery allows for precise positioning of zygoma implants, which may represent a valuable option for patients with severe maxillary bone atrophy [van Steenberghe et al. 2003; Vrielinck et al. 2003; Kreissl et al. 2007; Chow et al. 2006]. A further beneficial aspect is the associated automatic and complete electronic documentation which is increasingly important in modern quality assurance and management [Ewers et al. 2004].

Problems and Future Perspectives

Computer- aided implant surgery requires substantially greater investment and effort than the standard technique.

(1) Compared to conventional imaging, CT is more expensive and includes a higher exposition to ionizing radiation. Low dose MSCT protocols can significantly reduce radiation dose but dose levels for CBCT imaging remain far below those of MSCT protocols [Mozzo et al. 1998; Lenglinger et al. 1999; Schom et al. 1999; Arai et al. 1999; Gahleitner et al. 2001; Sucovic et al. 2001; Nakagava et al. 2002; Ziegler et al. 2002; Cohnen et al. 2002; Hatcher et al. 2003; Loubele et al. 2005, 2008c]. It is important to note that CBCT is still equivalent to the exposure from a full-mouth periapical series and a clear indication has to be given [Loubele et al. 2008c]. CBCT is not dependent on larger radiology centers and due to its small size resembling dental panoramic radiography it can be provided in dental practice at substantially lower costs. In oral implant surgery, CBCT is the medium of future and will displace MSCT [Guerrero et al. 2006].

(2) Surgical navigation systems cost about \$60,000 to \$200,000 US and are hardly affordable for practitioners. In larger institutions, these systems can be used for a wide range of craniomaxillofacial procedures (eg. image-guided biopsies, removal of foreign bodies, arthroscopy of the temporomandibular joint, osteotomies, distraction osteogenesis and tumor surgery) [Widmann 2007; Heiland et al. 2004; Ewers et al. 2005]. Compared to standard surgery, registration and navigation add to the surgical time and may require ergonomic compromises for the surgeon’s team, as the tracking elements on the registration template and the drill need constant visual contact to the stereoscopic camera array [Kramer et al. 2005]. During navigation the surgeon has to look at the screen and cannot simultaneously look at the

operative site and the screen. To compensate this problem head mounted displays or a flexible mini screen were used [Wanschitz et al. 2002a]. Electromagnetic navigation systems do not need visual contact between instrument and sensor system but are susceptible to interference by external magnetic fields and metal objects (particularly with drilling and sawing tools) [Wagner et al. 1996, 2002; Hassfeld and Muehling 2001]. Incorrect position sensing of up to 4 mm may occur and special titanium or ceramic instrument set is required [Birkfellner et al. 1998; Marmulla et al. 1998; Gunkel et al. 2000]. So far, there is no realistic alternative to optical based navigation systems. A further technical improvement of active guidance is to enhance the operator performance by linking the drill speed to the operator accuracy [Brief et al. 2005; Widmann 2007]. When the position and angle of the drill stand outside a certain degree of accuracy, the drill will slow down or will automatically stop before reaching a vital anatomic structure.

(3) Compared to standard drill guides, image-guided template production needs registration templates, a special positioning device or rapid prototyping technology, which implies more expenditure. However, costs are lower than with navigation. The template is usually fabricated by a remote company and the oral surgeon or laboratory technician may not need to purchase expensive hardware. Compared to navigation, surgical templates lack interactive control and modifications during the operative procedure are not possible. Depth gauges or a stop on the drill are needed to control the location of the drill relative to underlying structures.

As a prerequisite, the dimensions of the bur tubes have been adopted to the surgical drill set. Surgical templates may not be used due to jaw limitations (surgery in distal location), thus sufficient mouth opening has to be verified prior to surgery [Naitoh et al. 2000; Fortin et al. 2002]. Due to the less expenditure and possible outsourcing, passive guidance technology is more commonly used than active guidance and may hold this position.

Conclusion

Computer-aided oral implant surgery can be realized via surgical navigation systems (active guidance) and surgical templates (passive guidance). Correct indications, technical limitations and sources of errors have to be acknowledged. Based on clinical data, computer-aided oral implant surgery is not required for easy cases with sufficient anatomic orientation and bone height.

However, patients may fully benefit from the advantages of 3D imaging, computer-aided planning, and image-guided surgery when a CT scan is recommended as a diagnostic means, when prosthodontic-driven implant positioning has to be precisely executed, when safe positioning of implants with maximum length is desired for optimal use of the available bone, and when flapless surgical approaches and immediate loading concepts are considered. As new technology becomes cheaper and broadly available with time, computer-aided implant surgery will gain increasing importance as a standard therapeutic strategy.

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Chapter 12

A Computer-Aided Oral Implantology System in the Placement of Zygoma Implants for Maxillary Reconstruction

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Abstract

During the past decades, rehabilitation of maxillary defects still poses a significant challenge for both surgeons and prosthodontists. The advent of zygoma implants presents a unique alternative for maxillary reconstruction without the need for grafting, allows for secure, esthetic, and functional replacement of ablated hard and soft tissues, while minimizing prosthetic complications. However, the placement of zygoma implants is not without risk due to the anatomically complex operation sites and the implant length. In this study, an image guided oral implantology system (IGOIS) is presented to enhance the safety of patients by reducing the risk of damage to adjacent anatomical structures. On the basis of the preoperative data of the CT-scanned patient, surgical planning is accomplished, including 2D/3D geometrical measurements, bone density analysis, bone volume measurement for maxillary defects, optimization design of the position and orientation of oral implants, etc. With the support of an optical tracking device, real-time navigation is achieved through a point-based registration method so that all the preoperative determined implant sites can be drilled carefully according to the original plan under the guidance of 2D/3D interactive image rendering environment. In the following clinical report, IGOIS was successfully used in the treatment for a patient who underwent maxillary resection due to oncology. After the placement of a total of 4 zygoma implants, the patient was CT-scanned, and then the postoperative images were aligned with the initial planning ones through an automatic image registration method. The result shows that the average distance deviations at the coronal and apical point of

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the zygoma implant are 1.28 mm (range: 0.8 to 1.8) and 1.68 mm (range: 1.4 to 1.9), and the average angle deviation is 4.10° (range 2.5° to 5.8°), therefore, demonstrates that IGOIS is an accurate method for transferring the planning of a complex osteotomy to the actual surgical procedure.

Keywords: Computer-aided surgery; Oral implantology; Zygoma implant; Registration.

Introduction

Nowadays, maxillary rehabilitation still poses a significant challenge for both restorative and surgical colleagues. Although there are several reconstructive options including prosthetic obturation, nonvascularized grafts, local flaps, regional flaps, and microvascular free tissue transfer, surgical reconstruction of maxillectomy defects continues to be unpredictable, and not always possible due either to local or systemic reasons[1]. The advent of zygoma implants has drastically revolutionized maxillary reconstruction because the implant placement procedure does not require any adjunctive procedure. In addition, these implants can be successfully used to support a maxillary overdenture or a fixed bridge [2-5].

However, implant placement in the zygoma and pterygoid bone, can be difficult due to the variable anatomy and varying degrees of atrophy possible in the maxillofacial region. Furthermore, because the drill path is close to critical anatomical structures such as maxillary sinus, nasal cavity, eyes, etc., a small angular error may result in serious problems at the end of the tool trajectory. Nevertheless, the limited intraoperative visibility, the vicinity of critical anatomical structures, as well as the inherent intricacies of the curved zygomatic bone, makes this type of surgery a demanding procedure [1, 6]. One solution to this problem is the use of a reliable computer-aided intraoperative navigation system, which has been widely used in neurosurgery, orthopedic surgery, otorhinological surgery, and maxillofacial surgery. With the introduction of the computer-aided navigation system, the interactive, intraoperative application of three-dimensional image data can be realized so that the precision achieved in the planning phase can be transferred to the patient [7]. In this study, we present the dental navigation technology which integrates 3D medical modeling, preoperative surgical planning, registration and intraoperative tracking into an image guided oral implantology system (IGOIS). With the aid of IGOIS, the feasibility and reliability of oral implant surgery in anatomically complex operation sites can be improved. A clinical report highlights the benefits of the computer-aided navigation in zygoma implant surgery.

Materials and Methods

The Framework of IGOIS

The Framework of IGOIS shown in Figure 1 is described as follows: On the basis of the preoperative data of the CT-scanned patient, image processing (including filter, reformatting,

and segmentation) is conducted so that the series of 2D axial, user-defined panoramic, and cross-sectional images are obtained.

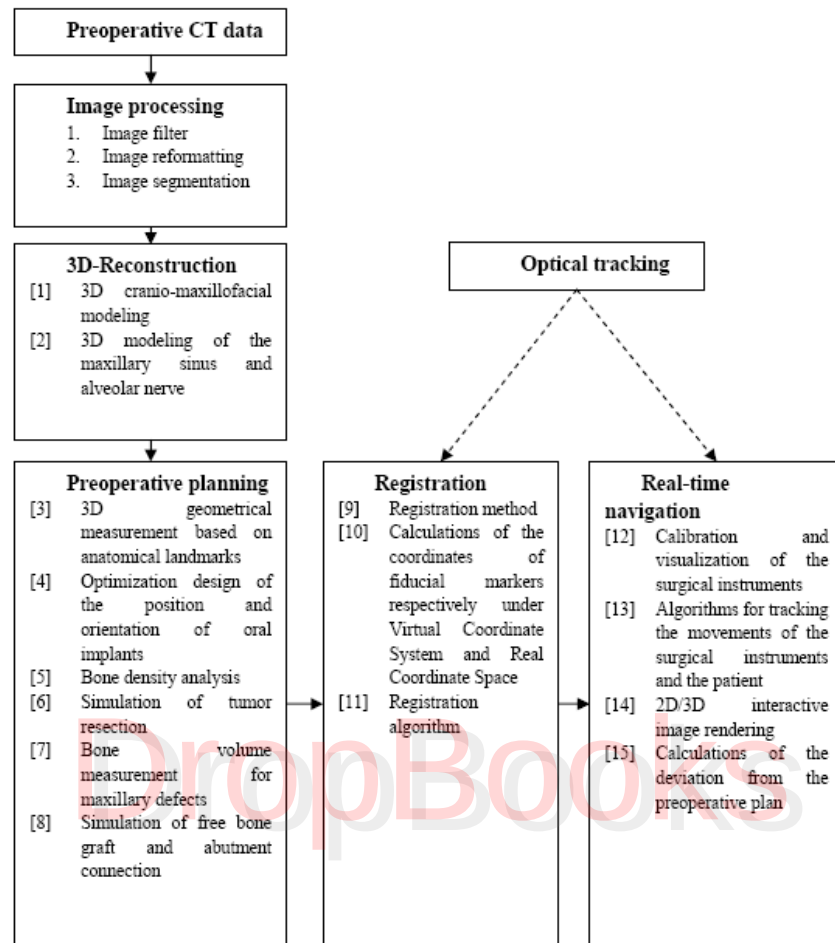


Figure 1. The framework of IGOIS.

Then, 3D-reconstruction of the cranio-maxillofacial structures (including the maxillary sinus and the inferior alveolar nerve) is realized. Based on the series of 2D images and the 3D models, preoperative planning is accomplished, including 2D/3D geometrical measurements, optimization design of the position and orientation of oral implants, bone density analysis, bone volume measurement for maxillary defects, simulation of tumor resection and free bone graft, etc. Then, with the support of the optical tracking device, registration is performed to determine the spatial relationship between Virtual Coordinate System (VCS, refer to as the preoperative image coordinate system) and Real Coordinate Space (RCS, refer to as the patient coordinate system). Finally, with the use of the tracking device, real-time navigation is achieved through motion tracking algorithms, as well as calibration and visualization of the surgical instruments, so that all the preoperative determined implant sites can be drilled carefully according to the original plan under the guidance of 2D/3D interactive image rendering environment.

Preoperative Surgical Planning

With the original CT data, a threshold and region growing combined method is adopted for the segmentation of the object bone tissue so that 3D cranio-maxillofacial surface model is reconstructed through the marching cubes algorithm [9] and triangular surface decimation method[10]. After 3D-Reconstruction, the CT data and the cranio-maxillofacial model will be imported to CAPPOIS (Computer Assisted Preoperative Planning for Oral Implant Surgery, a special software developed by our institute) for preoperative surgical planning. First of all, prosthodontists draw manually a panoramic curve following the curvature of the jaw bone on one of the imported axial CT image slices. On the basis of this panoramic curve, the series of panoramic images and cross-sectional images are reconstructed. Then, anatomical landmark points on these 2D images or the 3D cranio-maxillofacial model can be located so that the distance between any two points and the angle among any three points can be calculated. In addition, bone density can be measured by locating a certain area on the 2D images, as well as bone volume measurement for maxillary defects can also be done. According to the above-mentioned information concerning the relevant anatomical structures, prosthodontists can select a certain type of virtual implants and place them into the ideal areas. The virtual implants will be rendered on all of the 2D/3D views; therefore, the type, number, size, position, and orientation of the implants can be determined explicitly by iterative optimization taking into account prosthetic requirements and available local bone. An example for a preoperative plan with CAPPOIS is shown in Figure 2.

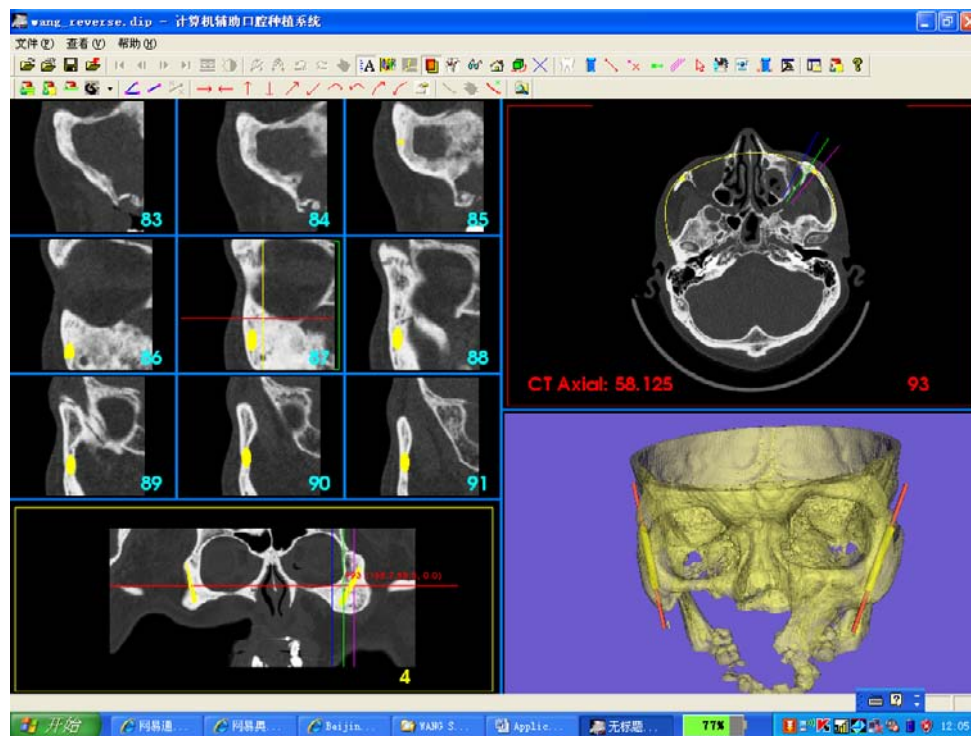


Figure 2. A plan is created for the ideal positioning of the zygoma implants, in both 2D and 3D, while taking into account both clinical and esthetical considerations.

The user interface and functions of CAPPOIS parallels Simplant (Materialise, Belgium)[8], which is already commercially available, however, since the visualization and image processing algorithms involved in our software are developed using Visualization Toolkit (VTK, an open source, freely available software system for 3D computer graphics, image processing, and visualization etc., <http://www.vtk.org/>) and Insight Toolkit (ITK, an open-source software toolkit for performing registration and segmentation, <http://www.itk.org/>), a plug-in evolutive software architecture is established, allowing for expandability, accessibility, and maintainability in our system. In addition, aiming to make the software simply accessible and fulfill the research requirements in academia, our future work is to make CAPPOIS a free, open source, and cross-platform (Windows, Linux and Mac Os X operating systems) software for preoperative planning in oral implantology.

Registration

The basic requirement of any navigation technique is the registration of the patient's position in relation to the image data set [11]. The choice of the registration procedure has a decisive influence on the navigation accuracy [11, 12]. A variety of registration methods, including anatomical landmarks, miniscrews inserted preoperatively into the bone, and surface based concepts, are proposed [12, 13]. Among them, the registration with anatomical landmarks is not precise enough, with divergences of 2–5 mm described [12,13]. Although the skin surface registration has become adaptable for clinical practice, this markerless technique needs a special laser scanning device [12-15]. The method based on artificial markers are less convenient or may be invasive; nevertheless, it helps reduce human error associated with landmark identification and hence tend to improve the registration accuracy [12-15]. In this study, therefore, the artificial marker-based registration method is adopted.

Now, we need to get the coordinates of the fiducial markers respectively under the two coordinate systems: the operation site and the image site, and then obtain the registration transformation matrix. An image recognition technique for automatic finding and localizing the centroids of the fiducial markers is adopted [16], so that the coordinates of fiducial markers under Virtual Coordinate System (VCS) can be obtained. Meanwhile, with the monitor of the optical tracking system (In IGOIS, the Polaris hybrid optical tracking device NDI Inc. , Canada is used), their coordinates under the coordinate system determined by the rigid assembly can also be obtained. The principle is described as follows:

Five 3-dimensional coordinate systems can be established as shown in Figure 3, respectively World Coordinate System XYZ determined by the optical tracking system; Virtual Coordinate System $X_0Y_0Z_0$ (also referred as to the image coordinate system) determined by the original CT data; Reference Coordinate System1 $X_1Y_1Z_1$ (also referred as to the patient coordinate system) determined by the rigid bracket assembly mounted on the registration template; Reference Coordinate System2 $X_2Y_2Z_2$ determined by the positioning probe; and Reference Coordinate System 3 $X_3Y_3Z_3$ determined by the surgical instrument, while $A1(R_1, T_1)$, $A2(R_2, T_2)$, and $A3(R_3, T_3)$ are the tranformation matrices with which Reference Coordinate System1, 2, and 3 can be respectively transformed to World Coordinate System (where R_1 , R_2 , and R_3 are the rotation matrices, and T_1 , T_2 , and T_3 are the translation matrices),

and $A0(R_0 \ T_0)$, and $A10(R_{10} \ T_{10})$ are the registration transformation matrices with which World Coordinate System and Reference Coordinate System1 can be respectively transformed to Virtual Coordinate System (where R_0 , and R_{10} are the rotation matrices, and T_0 , and T_{10} are the translation matrices). On the basis of theories of spatial mechanisms and analytical geometry, the following analysis can be done.

(1) To obtain the coordinates of fiducial markers under World Coordinate System

Suppose $X = (x \ y \ z)^T$ is the coordinates of a fiducial marker under World Coordinate System, and $X_2 = (x_2 \ y_2 \ z_2)^T$ is the coordinates of this fiducial marker under Reference Coordinate System2, hence,

$$X = R_2 X_2 + T_2 \quad (1)$$

(2) To obtain the coordinates of fiducial markers under Reference Coordinate System 1

Suppose $X_1 = (x_1 \ y_1 \ z_1)^T$ is the coordinates of this fiducial marker under Reference Coordinate System1 (the patient coordinate system), hence,

$$X = R_1 X_1 + T_1 \quad (2)$$

According to the equations (1) and (2), thus, $R_2 X_2 + T_2 = R_1 X_1 + T_1$

$$\text{hence, } X_1 = R_1^{-1}(R_2 X_2 + T_2 - T_1) \quad (3)$$

In the Polaris optical tracking system seven elements $(a_0, a_1, a_2, a_3, a_4, a_5, a_6)$ are used to describe the transformation of a rigid body under World Coordinate System. The 4 former ones represent the unit quaternion, i.e. $a = a_0 + a_1 \vec{i} + a_2 \vec{j} + a_3 \vec{k}$,

where $a_0^2 + a_1^2 + a_2^2 + a_3^2 = 1$, thus, the corresponding 4×4 rotation matrix R is:

$$R = \begin{bmatrix} a_0^2 + a_1^2 - a_2^2 - a_3^2 & 2(a_1 a_2 - a_0 a_3) & 2(a_1 a_3 + a_0 a_2) \\ 2(a_1 a_2 + a_0 a_3) & a_0^2 + a_2^2 - a_1^2 - a_3^2 & 2(a_2 a_3 + a_0 a_1) \\ 2(a_1 a_3 - a_0 a_2) & 2(a_2 a_3 + a_0 a_1) & a_0^2 + a_3^2 - a_1^2 - a_2^2 \end{bmatrix}.$$

The 3 latter ones represent the translation vector T , i.e. $T = (a_4 \ a_5 \ a_6)^T$.

Therefore, R_1, R_2, T_1, T_2 are all known, meanwhile, X_2 , the coordinates of this fiducial marker under Reference Coordinate System2, is also known (i.e. the coordinates of the tip point of the positioning probe under Reference Coordinate System2, for the convenience of computing, the origin of Reference Coordinate System2 is usually supposed to be located at the tip point, then $X_2 = (0 \ 0 \ 0)^T$). Substitution of the above results into Equation (1)

and (3) leads to the coordinates of fiducial markers respectively under the world and patient coordinate systems. If $X_2 = (0 \ 0 \ 0)^T$, then $X = T_2 \quad X_1 = R_1^{-1}(T_2 - T_1)$.

Finally, the registration transformation matrices, $A0(R_0 \ T_0)$ and $A10(R_{10} \ T_{10})$, can be obtained through ICP Iterative Closest Point algorithm [17].

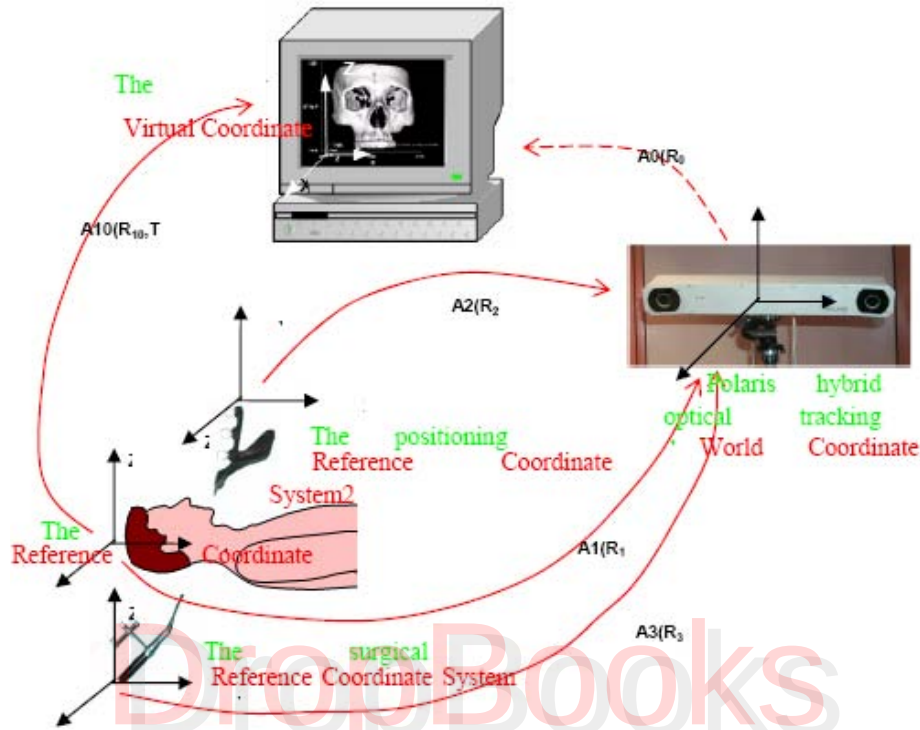


Figure 3. The establishment of the coordinate systems.

Motion Tracking Algorithm

The motion tracking algorithm can be described as follows:

At first, the absolute movement of the surgical instrument under World Coordinate System is transformed to the relative movement under the patient coordinate system. Then, this relative movement is transformed to Virtual Coordinate System after applying the registration transformation matrix between the patient and virtual coordinate system (i.e. $A10$, which is obtained according to the above-mentioned analysis). Therefore, during the procedure of the surgical navigation, although the actual position of the patient has been continuously changing, the 3D cranio-maxillofacial model of the patient rendered on the computer screen remains absolutely stationary, only the position and orientation of the surgical instrument model varies with the spatial relationship between the patient head and the surgical instrument. The advantage of this motion tracking algorithm lies in its improved time and space efficiency otherwise the cumbersome 3D cranio-maxillofacial model has to be translated, rotated and re-rendered all the time during the procedure. The tracking algorithm can be expressed in mathematical expressions as follows:

Suppose $X = (x \ y \ z)^T$ is the coordinates of any point under World Coordinate System, $X_0 = (x_0 \ y_0 \ z_0)^T$ is the coordinates of this point under Virtual Coordinate System, $X_1 = (x_1 \ y_1 \ z_1)^T$ is the coordinates of this point under Reference Coordinate System1 (the patient coordinate system), $X_3 = (x_3 \ y_3 \ z_3)^T$ is the coordinates of this point under Reference Coordinate System 3(the surgical instrument coordinate system), hence,

$$\begin{cases} X = R_1 X_1 + T_1 \\ X = R_3 X_3 + T_3 \\ X_0 = R_{10} X_1 + T_{10} \end{cases} \quad (4)$$

To simplify the form and operation of the above equations, a homogeneous coordinate $t=1$ is introduced here, i.e. $X = (x \ y \ z \ 1)^T$

$$\begin{aligned} X_0 &= (x_0 \ y_0 \ z_0 \ 1)^T \quad X_1 = (x_1 \ y_1 \ z_1 \ 1)^T \quad X_3 = (x_3 \ y_3 \ z_3 \ 1)^T, \\ A1 &= \begin{pmatrix} R_1 & T_1 \\ 0 & 1 \end{pmatrix}, A10 = \begin{pmatrix} R_{10} & T_{10} \\ 0 & 1 \end{pmatrix} \quad A3 = \begin{pmatrix} R_3 & T_3 \\ 0 & 1 \end{pmatrix}. \end{aligned}$$

Hence, the 3-by-3 matrices are equivalent of the following 4-by-4 matrices:

$$\begin{cases} X = A1X1 \\ X = A3X3 \\ X0 = A10X1 \end{cases} \quad (5)$$

According to the first two equations of (5), thus, $A1X1 = A3X3 \Rightarrow X1 = (A1)^{-1} A3X3$

Substitution of the above results into the third equation leads to:

$$X0 = (A10)(A1)^{-1} A3X3 = \begin{bmatrix} R_{10} & T_{10} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} R_1 & T_1 \\ 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} R_3 & T_3 \\ 0 & 1 \end{bmatrix} X3 = \begin{bmatrix} R_{10}R_1^{-1}R_3 & R_{10}R_1^{-1}(T_3 - T_1) + T_{10} \\ 0 & 1 \end{bmatrix} X3$$

So, the motion tranformation matrix is $\begin{bmatrix} R_{10}R_1^{-1}R_3 & R_{10}R_1^{-1}(T_3 - T_1) + T_{10} \\ 0 & 1 \end{bmatrix}$, through which

the position and orientation of the surgical instrument model varies on the computer screen in real time so that the navigation procedure is realized. In addition, the position and orientation deviation from the preoperative plan is also calculated and displayed in real time, and if it exceeds the preset threshold (The tolerances for distance deviation (mm) and angle deviation ($^\circ$) are respectively 1mm and 3° so that human error can be controlled within reasonable limits to ensure the total precision of implant placement), an alarm message will appear on the computer screen. All of the functions including the registration and motion

tracking are programmed in Microsoft Visual C++ and the Visualization ToolKit, and then integrated into the software of IGOIS.

Clinical Case Report

The advantage of IGOIS is validated through clinical applications. In this report, we describe the application of this specialized surgical navigation system for the planning and subsequent precise placement of zygoma implants in a patient with maxillectomy defects (the general information about this patient is listed in Table 1).

First of all, totally 8 titanium miniscrews were inserted preoperatively into the palatine and distributed in different orientations as fiducial markers for registration. Then, the patient was scanned via a 16-slice spiral CT scanner (GE, LightSpeed, 140KV/250Ma, 0.625mm slice thickness, 512*512 matrix). After that, the CT data were imported to CAPPOIS for 3D-reconstruction and preoperative planning. For this case, according to the discussion of the clinical team, a “quad” approach was recommended for maxillary reconstruction, supporting a denture with 2 bilateral zygoma implants on each side (shown in Figure 4).

Table 1. The general information about the patient with maxillectomy defects

Case	Gender	Age	Diagnosis	The prosthodontic rehabilitation method to adopt
1	Male	43	Maxillectomy defects in the right region	2 bilateral zygoma implants on each side

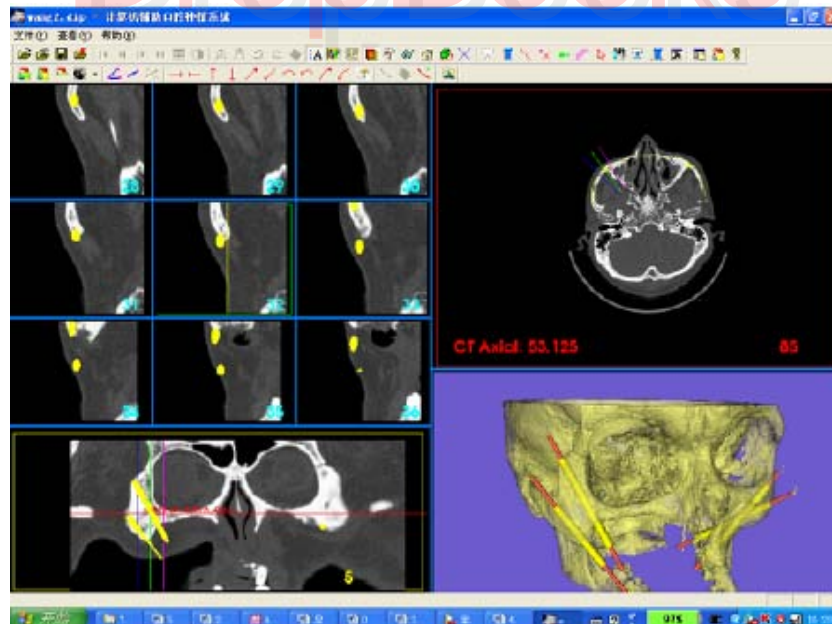


Figure 4. Preoperative planning with CAPPOIS.



Figure 5. the rigid bracket assembly mounted to the patient's head for the purpose of tracking its movement.

The treatment plan was designed to make optimal use of the bone volumes while protecting the critical anatomical structures especially the eyes, and finally transferred to IGOIS.

On the day before the surgery, all of the surgical instruments, including the drills, the rigid bracket assemblies and the retro-reflective balls for tracking, the positioning pointer, etc., were sterilized, and the hardware and software of IGOIS were both checked to be well-functioned. On the second day, after the patient was in general anaesthesia and the relevant preparative operations were accomplished, the dentist mounted the rigid bracket assemblies respectively to the patient's head (shown in Figure 5) and the drill, and determined the offset vector of the implant drill tip relative to the rigid bracket assembly using a calibration tool. Then, the surgical navigation procedure began. The dentist used a positioning probe to collect the coordinates of the fiducial titanium screw markers on the palatine so that registration was automatically accomplished by IGOIS (The registration procedure is shown in Figure 6). After registration, there was constant visualization of the drill trajectory on the computer screen (shown in Figure 7), while deviation from the preoperative plan position was detected and displayed in real time. Finally, under the guidance of IGOIS, the placement of all of the 4 zygoma implants was accomplished (shown in Figure 8).

After the surgery, the patient was CT scanned, and then the postoperative images were aligned with the initial planning ones through an automatic image registration method using maximization of mutual information. Resulting deviations between the planned and the actual implants are shown in detail in Table 2.

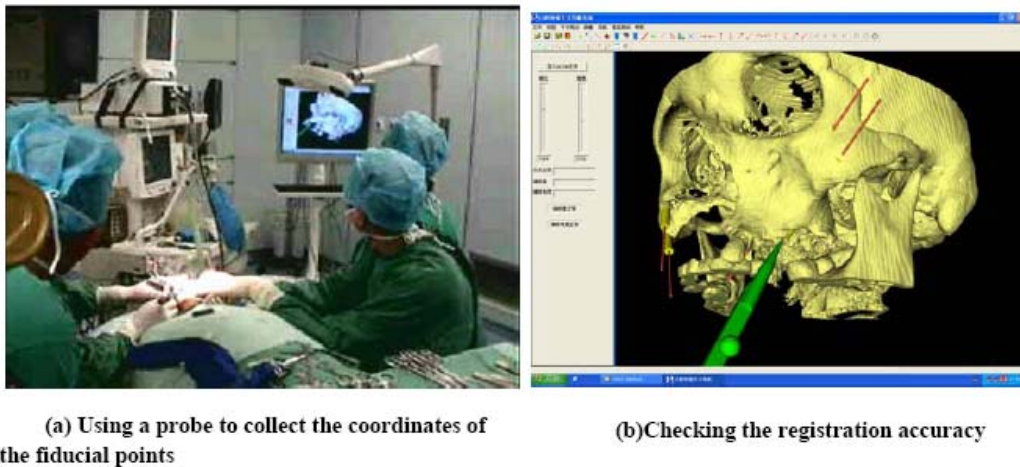


Figure 6. The registration procedure.

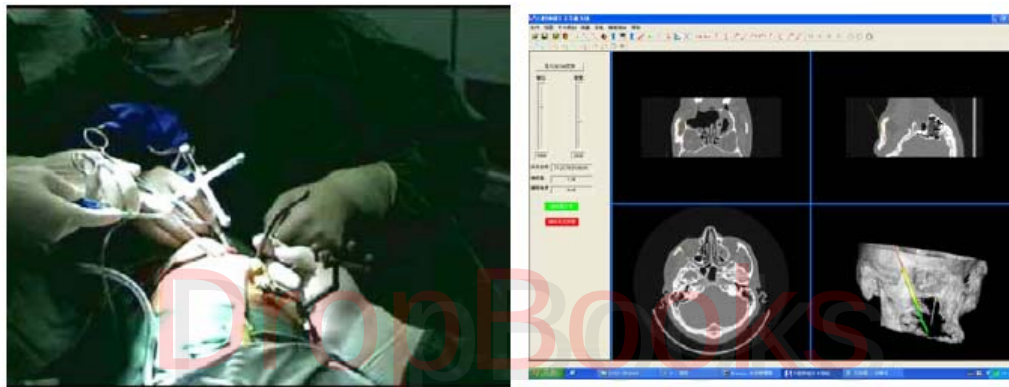


Figure 7. The surgical navigation procedure and the screenshot of the software interface.



Figure 8. inserting the zygoma implant.

Table 2. Resulting deviations

Implant No.	Distance deviation (mm) at the coronal point	Distance deviation (mm) at the apical point	Angle (°)
1	1.8	1.9	5.8
2	1.1	1.6	4.2
3	0.8	1.4	2.5
4	1.4	1.8	3.9
Mean	1.28	1.68	4.10
SD	0.43	0.22	1.35

The result shows that the average distance deviations at the coronal and apical point of the zygoma implant are 1.28 mm (range: 0.8 to 1.8) and 1.68 mm (range: 1.4 to 1.9), and the average angle deviation is 4.10° (range 2.5° to 5.8°), therefore, demonstrates that IGOIS is an accurate method for transferring the planning of a complex osteotomy to the actual surgical procedure..

Conclusion

The introduction of zygoma implants presents a unique alternative for rehabilitating the severely resorbed maxilla. Due to the anatomic intricacies of the zygomatic bone and the implant length, the placement of zygoma implants still poses a challenge for prosthodontists. In order to minimize the risks of the surgery, an image guided oral implantology system (IGOIS) is introduced in this study, including the framework, preoperative planning, registration, and the motion tracking algorithm. Although several computer-aided navigation systems for oral implantology have been presented in the literature, for example, VISIT (University of Vienna, Austria), IGI (DenX, Israel), RoboDent (RoboDent GmbH, Berlin, Germany), etc., their applications in zygoma implant surgery are rarely reported. The clinical report for a patient with maxillectomy defects shows that the average distance and angle deviations between planned and achieved position of the implant are respectively less than 2mm and 5°, therefore, demonstrates that IGOIS is very helpful and accurate in the placement of zygoma implants. However, more clinical cases will be done to demonstrate its feasibility and reliability.

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Chapter 13

Considerations in Dental Care in Implant-Treated Patients

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Abstract

Peri-implant pathology consists of an inflammatory process affecting the soft and hard tissues surrounding the implant, resulting in rapid loss of supporting bone associated with bleeding and suppuration. Mechanical therapy has been proven to affect bacterial infections and it has been suggested as a treatment modality around implants. Chemotherapeutic treatments are also considered essential in eliminating pathogenic organisms from the affected areas. In this view, the treatment of peri-implant mucositis comprises mechanical therapy, subgingival delivery of antiseptic agents, local application of antibiotics or the cumulative combination of above-mentioned treatments.

During the surgery, preoperative antibiotics may be considered to reduce the infectious complications. Applying antiseptic agent such as chlorhexidine before and after implant surgery may be beneficial. Exposed coverscrew may be removed to achieve better hygiene. Additional surgery such as bone graft or soft tissue graft may be needed to achieve better outcomes.

In this review, considerations in implant treatment before, during and after surgery will be reviewed. Various methods to control the peri-implant pathology will be discussed and the effect and efficacy of mechanical and chemotherapeutic treatment will be addressed.

Introduction

Dental implants are often used in rehabilitation of partially or totally edentulous patients and they have become an integral part of rehabilitative therapy [1]. Dental implants provide the patient and practitioner with additional options previously unavailable for enhancing function and esthetics [2]. Despite the high success rate shown by longitudinal studies, failures do occur, even in patients who present appropriate clinical conditions. Most failure occurred before loading and failure was more frequent when the implant was installed in the posterior jaw [3].

Peri-implant diseases may vary but it may be as high as 14% and this can limit clinical success and impose health and financial burdens to patients and health providers [4]. Peri-implant diseases include peri-implant mucositis, describing an inflammatory lesion of the peri-implant mucosa, and peri-implantitis, which also includes loss of supporting bone [5], and peri-implantitis may lead to loss of the implant [6]. It is reported that the inflammation around implants developed within a few weeks [7, 8], a few months [9], a few years [10], or up to 11 years [11].

Mechanical therapy has been proven to affect bacterial infections and it has been suggested as a treatment modality around implants [12]. Chemotherapeutic treatments are also considered essential in eliminating pathogenic organisms from the affected areas [13]. In this review, considerations in implant treatment before, during and after surgery will be reviewed. Various methods to control the peri-implant pathology will be discussed and the effect and efficacy of mechanical and chemotherapeutic treatment will be addressed.

Diagnosis

Peri-implantitis is often diagnosed by clinical findings such as pain, redness, tenderness, swelling, and sometimes the presence of a fistulous tract [14]. The thorough examination including the periodontal probing depth, the presence of bleeding on probing, suppuration and radiographs should be carried out regularly for the diagnosis of peri-implant diseases. It is reported that that probing using a light force (0.25 N) does not damage the peri-implant tissues [5]. Radiographs may aid in detecting loss of supporting bone and the baseline radiograph can be used as a reference in the longitudinal follow-ups.

Cause

Possible causes for infection includes overheating during the osteotomy, bacterial contamination from an adjacent tooth, residual bacteria from the infected tooth that previously occupied the site, bone microfractures from overloading or loading too soon, and residual space left around the implant after it is seated [15]. Presence of residual root fragments and foreign bodies in the bone, contamination of the implant, or implant placement

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in an infected maxillary sinus may lead to implant lesions [16]. A fenestration involving the middle portion of the implant may also lead to the implant periapical lesion.

The comprehensive history taking and thorough examination (including sensitivity testing, vitality testing and radiograph) before implant placement may prevent or reduce such complications.

Compounding Factor

The microbial composition of supra- and subgingival biofilm in subjects with and without peri-implantitis were compared and marked differences were observed in the composition of supra- and subgingival biofilm between healthy and diseased implants [17]. The microbiota associated with peri-implantitis was comprised of more periodontal pathogenic bacterial species, including the supragingival biofilm. It was also reported that the pathogenic species associated with periodontitis (e.g., *Fusobacterium ssp*, *A. actinomycetemcomitans*, *P. gingivalis*) were associated with peri-implantitis [4].

Patients with a history of chronic periodontitis may exhibit significantly greater long-term probing pocket depth, peri-implant marginal bone loss [18], and patients treated for periodontitis may experience more implant loss and complications around implants than non-periodontitis patients [19]. It is reported that patients with a history of aggressive periodontitis were more prone to late implant loss, even when supportive periodontal therapy was given [20].

The major influence on the peri-implant microbiota was the microbiota on remaining teeth. *P. gingivalis* and *B. forsythus*, and red complex periodontal pathogens, but the microbiota of successful implants was similar to that of periodontal health [21].

A tendency toward higher losses was reported when implants were also immediately loaded [22], and immediately loading protocol should be applied with caution.

Poor oral hygiene, and cigarette smoking are also reported to be risk indicators for peri-implant disease [5]. Peri-implant soft tissue health can be maintained with good oral hygiene irrespective if a keratinized gingival tissue zone surrounding implant but in reality, good oral hygiene is very difficult to achieve around dental restorations without the protection of a band of keratinized gingival tissue [23].

Implant Surface

The most commonly used material in oral implantology is commercially-pure titanium and the most commonly used oral implant design is the threaded screw implants [24]. The original treatment concept with a two-stage surgery with turned surface seemed to give very good results from follow-up over two decades [25].

The highest incidence of implant loss was reported with a very rough surface [26]. Greater loss of clinical attachment level was seen in sandblasted/acid-etched implant compared to smooth-surface implants when experimentally induced peri-implantitis beagle model was used [27]. Another study was done using four different implant systems

with different surface characteristics (turned, TiOblast, sandblasted/acid-etched and TiUnite) and it was reported that spontaneous progression of experimentally induced peri-implantitis was most pronounced in TiUnite surface [28]. Higher incidence of peri-implantitis was also seen with calcium-phosphate-coated or surface [4]. In case of supportive periodontal therapy, late implant loss remained below 3% and marginal bone loss remained low when roughened surfaces were avoided [26].

Preoperative Consideration

Applying antiseptic agent such as chlorhexidine before and after implant surgery may be beneficial [29]. Subgingival chlorhexidine irrigation may be a valuable adjunct to oral health on peri-implant maintenance [30]. No adverse events were recorded in using chlorhexidine besides discoloration and taste irritations [31]. However, water irrigation is reported to show a limited effect on the bacterial groups [32].

Treatment for chronic periodontitis should be performed before implant treatment [33], and full-mouth root surface debridement may be considered to reduce re-colonization by the bacteria and enhance healing.

Preoperative antibiotics may be considered because it can give maximum reduction of infectious complications and fewer implant failures [34, 35]. This may be applied in certain conditions such as diabetes, because diabetic patients may experience more infection than non-diabetics [36].

Exposed Cover Screw

Spontaneous early implant exposure may result in early crestal bone loss around submerged implants [37], and exposed cover screw may be removed to achieve better hygiene [38]. The influence of abutment connections and plaque control on the initial healing of prematurely exposed implants in the canine mandible was examined, and the results suggested that the placement of healing abutments and meticulous plaque control may limit bone loss around submerged implants when implants are partially exposed [37].

Mechanical Treatment

Mechanical therapy has been proven to affect bacterial infections and it has been suggested as a treatment modality around implants [12]. It was observed that mechanical non-surgical therapy may be effective in the treatment of peri-implant mucositis lesions and the adjunctive use of antimicrobial mouth rinses is reported to enhance the outcome of mechanical therapy of such mucositis lesions [39]. The erbium-doped yttrium aluminium garnet (Er:YAG) laser and the combination of mechanical debridement/chlorhexidine shows equally efficacious at 6 months after therapy in improving periodontal probing depth and clinical attachment level [40], but it was suggested that single course of treatment with

Er:YAG laser may not be adequate for stable results and additional use of the Er:YAG laser may be required [41].

It is suggested that non-surgical therapy may be less or not effective in peri-implantitis lesions. However, it is still open to question whether deeper peri-implant lesions can be adequately treated with mechanical debridement [42].

Chemotherapeutic Treatment

Chemotherapeutic treatments are also considered essential in eliminating pathogenic organisms from the affected areas [13]. The adjunctive use of minocycline microspheres is reported to be beneficial in the treatment of peri-implant lesions with the reduction of probing depths, but the treatment may have to be repeated [43]. Tetracycline fibers were also used to treat the peri-implant lesions with mechanical debridement and the result mean improvements in clinical parameters [44].

Surgical Treatment

Surgical treatment is suggested when the periodontal pocket depth was larger than 5mm and extensive bone loss was present [45].

Surgical removal of the dental implants was reported to avoid possible osteomyelitis [7]. On the contrary, the removal of implant may be avoided if the dental implant had a stable osseointegration and the complete debridement of lesion were performed [10]. A surgical approach with resection of the apical portion of the affected implants in combination with debridement was performed and partially resected oral implants remained osseointegrated and were well in function with a follow-up period up to 3 years [14].

Graft material was applied in surgical procedure because bone graft to supplement surgical curettage in peri-implant infection has been reported to show adjunctive effects [46]. Combination of grafting materials and a membrane is suggested in the surgical treatment of the osseous defects in peri-implantitis lesion [47], because superior treatment outcome was achieved with the combination of deproteinized bovine bone and non-resorbable membranes compared to graft material alone, membranes alone or a control flap procedure [48]. Resorbable collagen membrane was also applied to treat peri-implantitis in combination with nanocrystalline hydroxyapatite or a natural bone mineral and treatment procedures showed efficacy over a period of 24 months [49].

Autologous platelet rich plasma and tri-calcium phosphate in sandwich bone augmentation technique appeared to improve early wound healing [50]. Synthetic peptide, which is a group of replicated of type I collagen peptides involved in cell binding, was used with bovine bone in peri-implantitis. This peptide is known to bind with stem cells and stem cells and initiate the bone formation cascade by migration, proliferation, and differentiation [15]. This approach resulted in resolution of the associated signs and symptoms of infection and new bone formation [15].

Decontamination

Surface debridement of the fixture is an important step and needs to be carried out with extreme care to prevent damage to the fixture surface [9]. The granulation tissue around the implant was removed by using plastic, titanium or graphite curettes [9, 51, 52]. Some author suggested using plastic curette because the plastic curettes are reported to give less implant surface alteration [52].

The affected area is detoxified by chemical means to further remove endotoxins and other surface contaminants. Several protocols have been suggested including air-powder abrasives [53], citric acid [54], chlorhexidine [55], hydrogen peroxide [56], and laser [57]. Some authors suggested that the detoxification of implant surface only using irrigation with saline may be acceptable [58].

Tetracycline can be applied to the implant surface using cotton pledgets using irrigation with saline [58], and it is also reported that the surface conditioning with tetracycline does not seem to influence on its micro-morphology [59]. The decontamination of the implant surfaces with the carbon dioxide (CO₂) laser in combination with augmentative techniques was also reported to be an effective treatment method for peri-implantitis [57].

Conclusion

Various methods to control the peri-implant pathology were discussed and considerations in implant treatment before, during and after surgery should be made to avoid or reduce peri-implant lesions. Close monitoring of the patients should be emphasized to prevent both development of peri-implantitis and recurrence of periodontal infection. Further randomized-controlled studies evaluating treatment models of peri-implant lesions are needed.

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Chapter 14

Principal Mycoses of the Oral Cavity

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Abstract

Stomatological fungal infections feature various different aetiologies, pathogenesis and clinical presentations. The incidence of these infections is on the increase due to the higher numbers both of patients fitted with dental prostheses and orthodontic braces, and of patients suffering from diseases causing impairment of the immune system.

Oral mycoses can be primary infections (candidiasis, tricosporonosis and rarely zigomycoses) or secondary to systemic infections, such as dimorphic fungi (*Histoplasma*, *Blastomyces*, *Coccidioides*, *Sporothrix*).

Candidiasis is the most common mouth fungal infection. It has been demonstrated that *Candida albicans* is able to adhere strongly to the oral mucosa, in particular in diabetic and HIV patients and in subjects wearing dental braces. These mycoses can produce acute, chronic and mucocutaneous oral lesions in the hosts. Acute pseudomembranous candidiasis, better known as *thrush*, is the most frequent stomatitis due to *C. albicans*.

Non candidal oral infections can be caused by *Cryptococcus* spp or filamentous fungi (*Aspergillus* spp and zygomycetes), that are rarely primary pathogens for the mouth, the oral localization being more commonly secondary to a more serious, systemic infection.

The diagnosis of oral mycoses is mostly based on clinical examination, but microbiological analysis is necessary to identify the aetiological agents and thus institute opportune antifungal therapy. Many methods are now available for performing laboratory analyses, based on different principles, times and costs. Some recent reports have focused on comparisons of the principal characteristics of the more commonly available current laboratory diagnostic systems.

Introduction

Mycoses of stomatological type are a hot topic nowadays due to the increasing number of subjects fitted with dentures but also to the growing number of cases of stomatitis or esophagitis provoked by *Candida* in patients with HIV seropositivity or AIDS [4, 47]. Moreover, in view of the risk of dissemination of the etiological agent to other body sites, of the difficulties of clinical management owing to the onset of drug resistance and of the peculiar clinical features of these diseases especially in AIDS patients, a greater attention needs to be paid to the planning of appropriate prevention measures [69].

Mycoses are caused by microorganisms that are widespread in nature (yeasts or filamentous fungi), that may be eukariotic, heterotrophic, aerobic or optional anaerobic and live as saprophytes in the superficial soil or in decomposing organic matter, or can parasitize humans and other animals. According to their vegetative aspect, these microorganisms are subdivided into yeasts (unicellular) and moulds (pluricellular); some can take on either form according to the growth conditions (dimorphous fungi).

Yeasts reproduce by gemmation and can generate a chain of cells (pseudohyphae). In culture they form colonies with a shiny, creamy, or sometimes opaque and wrinkled appearance, similar to that of bacterial colonies.

Moulds consist of long filaments (hyphae) that can branch repeatedly: this leads to the formation of the mycelium that gives a fungal colony its cotton-like appearance. Hyphae can be divided into cells by septa (septate hyphae), or be multinucleated lacking a septum (coenocytic hyphae).

Mycoses of the oral cavity are classified according to their clinical and etiopathogenetic characteristics. They may have a primary localization (candidosis, tricosporonosis, zigomycosis), or secondary in more severe forms (aspergillosis), or can be disseminated like those provoked by *Cryptococcus neoformans* or by dimorphous fungi (*Histoplasma*, *Blastomyces*, *Coccidioides*, *Sporothrix*).

Candidiasis

Candidiasis is undoubtedly the most common human mycosis. It is provoked by yeasts belonging to the *Candida* genus, that are commensals of the oral cavity in healthy subjects and can also colonize the digestive tract. Clinical manifestations affect the mucosa (oral, vaginal) and surrounding tissues depending on various predisposing factors of both physiological (age, a high carbohydrate or low vitamin diet) and pathological type (immune deficiency, dysmetabolic disease, prolonged drug treatments) or else be due to poor oral hygiene especially in smokers and subjects fitted with dentures or dental braces [18, 51, 58].

Etiology. The *Candida* genus comprises about 200 species, only some fifteen of which are responsible for human infections. *C.albicans* is the most clinically significant species (70-75% of cases), although in recent years there has been a great increase in infections caused by *Candida* non-*albicans* species, the most frequent of which are *C.tropicalis*, *C.glabrata*, *C.krusei* and *C.parapsilosis* [15, 16].

Pathogenesis and clinical aspects. Host infection development depends on the infective agent characteristics. It has been demonstrated that the transformation of yeasts from commensals into parasites is linked to various factors, including the ability to adhere to the endothelial lining and to switch, as well as the production of proteolytic enzymes [42, 53, 60]. In particular, thanks to the ability of *C.albicans* to transform from a unicellular to a filamentous form, it can increase its adhesion powers and acquire the ability to invade the tissues [6]; moreover, in predisposed subjects it can enter the bloodstream and spread to the internal organs [65].

From the clinical standpoint oral candidiasis are subdivided into:

Acute Pseudomembranous Candidiasis

Also known as “thrush”, it is the most common form of stomatitis caused by *C.albicans*. It presents in the form of whitish spots that, if untreated, can evolve into confluent plaques (pseudomembranes) that are easily dislodged. The infection can spread to the whole buccal mucosa, involving the tongue and gums, spreading to the throat and inducing severe dysphagia with ulcerative lesions and painful erosions. It is important to make a differential diagnosis from hyperplastic chronic candidosis (oral leukoplachia). If the pseudomembrane can be detached, leaving an erythematous, bleeding surface, it is likely acute pseudomembranous candidosis.

Although thrush can affect people of all ages it is particularly common in newborns, especially if they are premature. In this case the pregnant mother may present vaginitis due to *Candida*, and the infant is infected when ingesting vaginal secretions during delivery. Oral mucosa lesions generally appear within three days of birth and may resolve spontaneously. The use of dummies also increases the incidence of oral candidosis, due to occlusion of the oral mucosa.

Thrush can also manifest in elderly subjects affected by COBD (chronic-obstructive bronchial disease) or fixed or mobile dentures, as well as in severely ill patients (e.g. cancer patients). It can degenerate and cause lesions of the adjacent mucosa (upper airways, esophagus); this complication is fairly common in AIDS patients. In such cases adequate treatment is essential.

Acute Atrophic or Erythematous Candidiasis

This can present as a complication of acute pseudomembranous candidiasis or after the administration of wide spectrum antibiotic therapy. It may affect any part of the oral mucosa, especially the palate and the tongue. The latter appears smooth, shiny and swollen, making it very difficult to swallow solid foods and hot or cold liquids. It differs from the pseudomembranous form because it lacks the superficial whitish plaques.

Acute Trophic Candidiasis (Median Lozangic Glossitis)

This lesion manifests in proximity to the V lingual nerve, being characterized by a reddened area, partially or totally deprived of papillae, that is depressed or mamelonated. There is no consensus as to whether *C. albicans* is the etiological agent of this chronic form, or else plays an opportunistic role, invading already damaged tissues.

Angular Cheilitis

This is localized at the corners of the mouth and is frequently associated with chronic atrophic candidiasis.

Clinical manifestations include erythema and ragades; it can be fostered by a poor dental implant or the use of old dentures, by epithelial maceration phenomena and nutritional deficiencies (vitamin B group). The most frequent etiological agent is *C.albicans*.

Chronic Atrophic Candidiasis

This is the most common form of oral candidiasis. It is often associated with mobile dentures and affects 60% of wearers, with a clear prevalence among those who fail to carry out accurate daily disinfection procedures. The disease is only apparent when the dentures are removed, and generally remains asymptomatic or associated with cheilitis of the corners of the mouth. Characteristic signs include: chronic erythema and edema of the hard palate where it is in contact with the dentures, a dry mouth and taste disturbances.

Chronic Hyperplastic Candidiasis (Oral Leukoplachia)

Unlike thrush, chronic hyperplastic candidiasis manifests with persistent papules or plaques that can be whitish or dark, irregular in shape, painful and erythematous, mostly present on the inside of the cheeks rather than on the tongue. It is most common in adult males. A smoking habit and the use of dentures are considered to be predisposing factors. This disease evolves to a malignant form in 15-20% of cases. It is still not clear whether an existing lesion is infected by *C.albicans* or else it is the yeast itself that caused the lesion.

Black Villous Tongue

This affliction is characterized by an abnormal growth of papillae due to faster keratinization and/or slower desquamation processes. It features episodes of spontaneous remission but tends to become chronic over time.

The process is asymptomatic and involves the median part of the dorsal tongue, leaving a brownish-black pigmentation due to the action of exogenous substances like tobacco, foods, mouthwashes or the presence of microorganisms. It can be considered a variant of oral

candidiasis with mycotic phenomena superimposed on a disease of another nature (eg. bacterial).

Chronic Mucocutaneous Candidiasis (CMCC)

This is characterized by the presence of prolonged, recurrent infections of the skin, mucosa or nails, that show lesions and signs of atrophy and erythema evolving into deep granulomatous processes. This clinical form is associated with both humoral (IgM and IgG deficits) and cell-mediated immune disorders. Other diseases can be associated with CMCC, such as hereditary autosomal recessive endocrine disorders (hypothyroidism, hypoparathyroidism and hypoadrenalism), tumours (thymoma, sometimes associated with myasthenia gravis), as well as iron, pyridoxin, folates and vitamin A deficiencies.

Diagnostic tests. Since the *Candida* genus is present as a commensal in many healthy subjects, simple isolation in the laboratory is often insufficient to verify the pathogenic role of these yeasts that are normally present on the oropharyngeal mucosa. Moreover, the myriad aspecific oral clinical manifestations make it difficult to formulate a differential diagnosis from other similar diseases. A correct diagnosis must therefore be based on a thorough clinical examination and various laboratory investigations (microscopy, cultures, histology, intratissue and immunological tests) that require a close collaboration between the clinician and the mycologist.

No less important, in order to discriminate between colonization and infection-disease, is the performance of tests to determine the oral mycotic load, generally by the Oral Rinse Solution (ORS) technique, and accurate identification of the species, especially in cases of recurrent episodes [38, 39]. Another crucial aspect is to determine the susceptibility spectrum to the various antifungal drugs (antimycogram) in vitro, bearing in mind the multiplication of resistant strains reported in recent years.

Histological examination can help to clarify the nature of doubtful lesions. In particular, this is advised in the diagnosis of chronic hypertrophic candidiasis.

Prevention. This is based essentially on a thorough assessment of predisposing factors, including diabetes and smoking habit, and on correct oral hygiene together with routine cleansing and disinfection of dentures and dental braces.

Cryptococcosis

The *Cryptococcus* genus includes spherical opportunist yeasts that generally lack a mycelium but have a small polysaccharide capsule (<2µm) that is an important virulent factor [8, 73]. Human exposure can occur everywhere (in old buildings, at the zoo, in cereal storehouses). The onset of the infection follows inhalation of the spores, so the primary localization is the lungs, from which it spreads through the bloodstream to the CNS. Clinical concern about this microorganism has dramatically increased since the advent of AIDS. Before 1981, cases of cryptococcosis were rare but since 1990 the first epidemics have been

recorded, including the one in New York in which about 1,200 cases of cryptococcal meningitis were reported in HIV positive subjects [17].

Etiology. There are two species of *Cryptococcus* that are pathogen for humans (*C. neoformans* and *C. gattii*) and 5 serotypes, namely *C. neoformans* var. *neoformans* (serotypes D and AD), *C. neoformans* var. *grubii* (serotypes A) and *C. gattii* (serotypes B and C) [24, 34].

C. neoformans is a ubiquitously distributed microorganism. It has been isolated in the soil and in the feces of birds like pigeons (*Columbia livia*), canaries and parrots [12, 13, 45]. Provided it is protected from the sunrays and high temperatures, the microorganism can survive in feces for long periods of time, resisting even natural drying of the vector matter. Subsequent airborne dispersion of the particles released from the biological substrate facilitates the spread of the microorganism and its inhalation by humans.

Instead, the natural reservoir of *C. gattii* is the koala bear (*Phascolarctos cinereus*), and it is endemic in Australia and temperate zones, where it is also frequently found on trees of the *Eucalyptus* genus [46, 64, 70].

Recently, some clinical cases due to minor species, such as *Cryptococcus laurentii* and *Cryptococcus albidus*, have also been reported [22, 55, 71].

Pathogenesis and clinical aspects. *C. neoformans* infection generally affects immune-depressed hosts, whereas *C. gattii* is more often isolated in immunocompetent subjects [36].

In AIDS patients *C. neoformans* induced meningoencephalitis is the most frequent opportunistic mycosis (80%), and causes a death rate of 30-40%, due particularly to the difficulty in eradicating the pathogen, the frequent recurrences and to systemic spread often associated with other infective complications [54]. Primary cutaneous and muco-cutaneous forms are relatively rare, while secondary forms account for 15% of disseminated infections [20, 36, 63]. Gastrointestinal cryptococcosis can manifest in absence of infections of the CNS or respiratory tract in patients undergoing steroid therapy or affected by chronic liver disease, and in splenectomized patients. There have been only sporadic reports of oral manifestations. In the literature, a case of cryptococcosis of the parotid gland is described in a patient wearing dentures who was infected by contaminated soil following a trauma of the oral cavity [31].

Diagnostic tests. A microbiological diagnosis of cryptococcosis is made by isolating the microorganism in samples of expectorate or broncho-alveolar lavage (BAL) if it is a pulmonary infection, in CSF and blood if it is disseminated, in biopsy samples if it is cutaneous or subcutaneous. The Ink test on CSF and a search for circulating antigens on serum and/or CSF samples are very valid laboratory tests for a rapid, accurate diagnosis [20].

Zygomycosis

Infections by zygomycosis are caused by filamentous fungi characterized by large coenocytic hyphae, generally saprophytic, that grow rapidly and are widely distributed in nature. They are generally considered to be opportunistic pathogens, although such clinical manifestations are no longer regarded as unusual, owing to the increase in diabetic subjects and in immunosuppressive therapies.

Two orders are of clinical concern: *Mucorales* and *Entomophthorales*.

Etiology. The order of *Mucorales* includes the genres most often implicated in human pathologies: *Rhizopus*, *Mucor*, *Absidia*, *Cuninghamella* [14, 57]. These microorganisms are responsible for acute, deep mycoses with a rapidly fatal evolution that generally affect immune-depressed patients, although some cases have been recorded even in healthy subjects [62, 74]. The most common species are *Rhizopus arrhizus*, *Rhizopus microsporus* and *Rhizomucor pusillus*.

Instead, the order of *Entomophthorales* is of limited concern in immunocompromised hosts, because the mycetes tend to cause infection in immunocompetent subjects following trauma but do not present the same degree of invasiveness as *Mucorales*. Two genres are known to be implicated in human disease: *Conidiobolus* and *Basidiobolus*, that are responsible for subcutaneous infections and less frequently, for disseminated forms [7]. Their natural habitat is the soil, decomposing plants, the feces of insects, reptiles and amphibia. Zygomycetes are common worldwide but cases of disease are most often recorded among the inhabitants of tropical areas and especially in Africa.

Pathogenesis and clinical aspects. Onset of the disease occurs after inhaling the spores only if there is a high infective load, the subject is immune-depressed (organ transplant or neutropenic patients) or has an underlying disease (diabetes or acidosis) [10]. The infection is initially localized in the paranasal sinuses and can then show an often fatal evolution, spreading to the brain (62%). Pulmonary zygomycosis generally affect hematological or severely neutropenic patients, while a skin infection manifests after skin trauma or burns [1, 40].

In the literature, cases of oral zygomycosis have most often been described in patients with leukemia or diabetes, with a primary localization on the palate or soft tissues of the mouth, or a secondary localization following pulmonary spread [3, 5, 21, 30]. A case of tongue mucormycosis was reported in a child affected by Down's syndrome hospitalized for acute gastroenteritis. The infection was thought to have been caused by a wooden tongue depressor used during the medical visit [59].

Diagnostic tests. A definitive diagnosis of zygomycosis is obtained by histology with or without isolation of the microorganism in culture, bearing in mind the known growth difficulties. The characteristic hyphae are better evident with Gomori-Grocott staining than PAS or Calcofluor White [57].

Aspergillosis

The term aspergillosis covers different clinical pictures caused by fungi belonging to the *Aspergillus* genus. The disease course depends on the type of infection, the quantity of conides inhaled and the general conditions of the host. It can manifest as an "opportunistic" form, localized in various organs and apparatuses of immunocompromised hosts undergoing prolonged immunosuppressive or chemoantibiotic treatment, or those affected by severe, debilitating disease, as well as patients who have undergone bone marrow or solid organ transplants [19, 50, 52]. The type of infection depends on the subject's overall conditions and the fungal species involved.

Etiology. The *Aspergillus* genus includes more than 180 species, about twenty of which are responsible for clinical manifestations. The main species are *A. fumigatus*, followed by *A. flavus*, *A. niger*, *A. nidulans* and *A. versicolor*.

Pathogenesis and clinical aspects. Although *Aspergillus* spores are very often inhaled, the disease is rare in healthy subjects. Clinical forms include colonization, invasive infections and allergic forms.

The worst form is the invasive, especially in immune-depressed subjects, with either a pulmonary or extrapulmonary localization. Cases of invasion of the paranasal sinuses (often in association with other mycetes) or of allergic bronchopulmonary aspergillosis are by no means rare in these subjects.

Instead, oral aspergillosis is rare and affects only hosts at particular risk or with an impaired immune system. A case of infection of the jawbone by *Aspergillus* spp has been reported after tooth extraction in a diabetic patient [29] and of the gums in a neutropenic patient affected by leukemia [48]. There has also been a report of a mixed infection by *Aspergillus* spp and *Mucor* spp at the oro-sinus level, in which ulceration processes progressively involved the palatal mucosa and bone tissue, the paranasal sinuses and the orbits [43].

Diagnostic tests. Since *Aspergillus* spores are normally present in the environment, laboratory data are often insufficient to make a definite diagnosis. In some cases the finding of circulating antigen and/or specific antibodies in the serum can support the diagnosis. In forms involving the oral cavity and paranasal sinuses only a biopsy can provide a certain diagnosis.

Mycoses Due to Dimorphous Fungi

Dimorphous fungi are microorganisms that can grow and transform, taking on a mycelial morphology in the external environment and a yeast-like form in the host tissues. It is the morphological transformation from a mould to a yeast that confers virulence to this microorganism.

The diseases caused by these microorganisms constitute the group of mycoses with a primary etiology, i.e. those able to cause disease even in immunocompetent subjects. The severity of the resulting infection depends on the quantity of spores inhaled, the duration of exposure and the immune status of the host [35].

Etiology. This group comprises fungi present in well defined, circumscribed geographic areas, so they are generally endemic mycoses: *Blastomyces dermatitidis* and *Histoplasma capsulatum* in North America, *Coccidioides immitis* in California, *Paracoccidioides brasiliensis* in South-America, *Penicillium marneffei* in South-East Asia. Instead, *Sporothrix schenckii* is geographically much more widespread [2, 41, 56].

Pathogenesis and clinical aspects. All mycoses due to dimorphous fungi can spread to other sites after a first, generally asymptomatic localization at the pulmonary level.

Blastomycosis (*Blastomyces dermatitidis*) can manifest at the level of the skeleton and urinary tract. Primary skin infections are rare [9, 49, 67].

Histoplasmosis causes chronic disseminated forms, or acute forms with a fatal outcome, especially in newborns or severely immunodepressed subjects [35]. In some cases *Histoplasma capsulatum* can spread from the lungs to the skin and oral cavity, creating ulcerative or nodular lesions of the mucosa [27, 23]. In some cases the primary manifestation is in the oral cavity, where lesions form in the gums, destroy the hard palate and extend to the maxillary sinus and nasal cavity. This type of oral presentation is often a sign of HIV infection [72].

Coccidioidomycosis, caused by *Coccidioides immitis*, can present with different clinical pictures. In about 60% of cases it is asymptomatic, while the remainder are benign syndromes ("Valley fever"), or may evolve into pulmonary or extrapulmonary disease [25, 28].

Paracoccidioidomycosis is a chronic systemic granulomatous disease caused by *Paracoccidioides brasiliensis*, that can manifest at the level of the oral, nasal and more rarely gastrointestinal mucosa [11, 56]. This pathogen sometimes draws an unusual picture, as in the case of a patient with paracoccidioidomycosis of the larynx that mimicked a carcinoma [26].

Sporotrichosis, caused by *Sporothrix schenckii*, generally manifests at the lymphocutaneous level [37].

Penicilliosis due to *P. marneffei* is an important problem in HIV positive patients [61]. In Thailand, this disease is the third cause of infection in patients with AIDS, after tuberculosis and cryptococcosis [66]. Apart from pulmonary localizations and disseminated forms, the fungus can cause skin lesions that may ulcerate and even affect the bone [44]. In some cases it can affect the oral cavity, and especially the mucosa of the palate, causing papular and ulcerative lesions [32, 33, 68].

Diagnostic tests. Because dimorphous fungi are extremely infectious, it is not recommended to isolate the pathogen from clinical samples. It is wisest to perform cytological or histological tests, supported by serological findings, especially in cases of histoplasmosis.

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Chapter 15

Prevention of Aspiration Pneumonia in the Elderly by Reducing Oropharyngeal Microflora

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Abstract

Aspiration pneumonia is one of the major causes of a lower QOL for the elderly, and also one of the major causes of elderly people's death. Prevention of aspiration pneumonia is, hence, necessary to maintain the QOL of the elderly. For prevention of aspiration pneumonia, countermeasures should be considered against each risk factor, such as aspiration, poor oral hygiene status, and decreased immunity. Yoneyama et al. reported that continuous oral health care could reduce the incidence of aspiration pneumonia in elderly people. To elucidate the role of oral health care in the prevention of aspiration pneumonia, Ishikawa et al. studied the change in pharyngeal bacterial flora by oral health care using three facilities for the elderly. The changes in pharyngeal total bacteria, *Streptococcus*, *Staphylococcus*, *Candida*, *Pseudomonas* and black-pigmented *Bacteroides* after intervention of professional cleaning of the oral cavity were observed for a 5-month period. These pharyngeal bacteria decreased or disappeared after performing the professional oral health care, i.e., cleaning of teeth, dentures, tongue, and oral mucous membrane by dental hygienists, once a week in each facility. The result

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suggests that weekly professional oral health care can prevent aspiration pneumonia in the dependent elderly through reducing pharyngeal flora. Oral care is also applied for perioperative patients to prevent respiratory infection after operation or for those in intensive care units.

“Through the mouth goes in disease, out of the mouth comes evil” — an old Chinese proverb.

Introduction

The mouth is the entrance to the respiratory and digestive tracts, hence, it is open to the outside and rich in nutrients and moisture. The mouth has a complex structure with the hardest tissue of the human body, teeth, and soft mucous tissues. The tooth surface is a non-shedding surface that allows microbes to be retained until intentionally removed. Dental plaque, a typical biofilm attached to the tooth surface, has to be removed by mechanical or chemical procedures. Mucous membranes in each part of the mouth, cheek, gingiva, tongue and lip, offers a different receptor to which specific microbes can adhere. Spaces between teeth and the surrounding gingiva, gingival crevice offer niches for anaerobic bacteria, where the oxygen concentration is extremely low. These conditions in the mouth allow microbes to form complex microflora of a significantly large number of species [1]. It is well known that around 700 species of bacteria and fungi live in the mouth. More than 10^{10} of bacteria per gram of dental plaque and more than 10^8 of bacteria per ml of saliva are found. In the near future, metagenomics may show more details of oral microflora, almost half of which are non-culturable [2].

Normal oral microflora are commensals that live in perfect harmony with human immune systems; however, they are sometimes pathogenic to humans in the oral region and other parts of the body. In the oral region, the most well-known diseases are dental caries and periodontal disease. Pulpitis, stomatitis and other purulent diseases are also caused by oral microbes. Moreover, oral microbes cause diseases in distant parts of the body by translocation. Diseases caused by oral microbes are: osteomyelitis [3], infective endocarditis, cardiovascular diseases, atherosclerosis, prosthetic device infection, aspiration pneumonia, and increased risk for the delivery of preterm, low-birth-weight infants [4,5]. *Streptococcus intermedius*, one of the oral commensals, is reported to be found in liver and brain abscesses [6,7]. Taking into account that oral microbes cause the systemic infections mentioned above, control of oral microflora is important not only for oral health but also for general health.

In developed countries, the increasing numbers of elderly people in nursing homes raise the issue of how to maintain the health of these populations. Infectious diseases often occur in the elderly in nursing homes [8,9]. Aspiration pneumonia in the elderly, especially those in nursing homes, lowers their QOL, and is a major cause of death [10]. To prevent aspiration pneumonia we have to know the etiology of the disease as well as the condition of the elderly in nursing homes. This chapter will summarize the etiology of aspiration pneumonia and discuss the role of oral health care in the prevention of disease, focusing on microbiology.

Aspiration Pneumonia in the Elderly in Nursing Homes

A three-year study of nursing home patients by Jackson et al. [9] revealed that the overall incidence of nursing home-associated infection was 7.1 infections/1,000 patient days. Among 788 infections, 362 (47%) were respiratory tract infections. Pneumonia is a leading cause of morbidity and mortality in the elderly [11], especially those in long-term care facilities, and the median incidence is 1/1,000 patient days [12]. As a result of the reduced ability of elderly people in nursing homes to keep their mouth clean, their oral health status is rather poor [13]. This poor oral hygiene status, together with other risk factors, may result in a high incidence of aspiration pneumonia in the institutionalized elderly [14].

The mortality of patients with pneumonia in nursing homes varies from 5% to 40% [12], and in the case of severe pneumonia, mortality rises to 57% [15]. Together with the high mortality from pneumonia in the institutionalized elderly, functional impairment from the disease also distresses elderly residents [16]. Functional impairment then becomes a cause of other diseases.

Etiology of Aspiration Pneumonia

The risk factors for pneumonia in the elderly in nursing homes or long-term care facilities have been analyzed by a number of reports. Vergis et al. [17] performed a case-control study in a long-term care facility, and demonstrated reported aspiration and sedative medication as risk factors. Retrospective analysis was performed by Terpenning et al. [18] among 358 elderly subjects with aspiration pneumonia. Risk factors in dentate patients are requiring help with feeding, chronic obstructive pulmonary disease, diabetes mellitus, the presence of important pathogens in dental plaque or in saliva, and risk factors in both dentate and edentulous patients are requiring help with feeding, diabetes mellitus and the presence of *Staphylococcus aureus* in saliva.

A review by Marik et al. [11] provided evidence supporting the concept that oropharyngeal aspiration, due to abnormalities in swallowing and of the upper airway protective reflexes, is an important etiologic factor leading to pneumonia in elderly people. Loeb [19] reported that factors suggestive of aspiration play a major role in the etiology of pneumonia in nursing homes and long-term care facilities, including older age, swallowing difficulty and the inability to take oral medications. Inadequate oral care is also suggested as a risk factor in this article. Coleman [20] listed risk factors for pneumonia in nursing homes, and suggested that the most common route for developing pneumonia in the elderly is the aspiration of bacteria colonizing the oropharynx and the failure of the host defense mechanism to eliminate bacteria. Bacterial colonization on the oropharynx increases with poor oral hygiene, reduced salivary flow, tube feeding, debility, malnutrition and neoplasm.

Silent aspiration was observed in 71% of "healthy elderly patients" with community-acquired pneumonia [21]. Even in healthy adults, during deep sleep the incidence of aspiration of pharyngeal contents was 45% [22]. Silent aspiration of pharyngeal bacteria can cause pneumonia only related to 1) massive inoculum, 2) decreased host defense, and 3)

virulent organisms [23]. From this point of view, poor oral hygiene may provide sufficient bacteria and, moreover, opportunistic respiratory pathogens from the oral region to the pharynx, raising the possibility of pneumonia. Dental plaque and biofilms in the gingival crevice and on the surface of the tongue are potent sources of causative agents of pneumonia. The oral hygiene status of the institutionalized elderly is usually rather poor [13,24], and periodontal disease needs special attention when patients are dentate [25]. In the edentulous elderly with dentures, a biofilm called denture plaque forms on the denture surface. A high correlation between the bacterial species in denture plaque and pharyngeal microflora has been reported [26]; hence, denture plaque is a potent reservoir of pathogens causing aspiration pneumonia.

A variety of bacteria have been reported as causative organisms of aspiration pneumonia, including members of indigenous oral flora and nosocomially acquired pathogens [27-30]. Indigenous flora contain viridans streptococci, periodontopathic bacteria and *Moraxella catarrhalis*, and nosocomially acquired pathogens include *Staphylococcus aureus*, Enterobacteriaceae and *Pseudomonas* species [29]. Finegold [29,31] reported a high incidence of aspiration pneumonia by anaerobic bacteria, followed by reports that showed periodontal pathogens as causative agents of aspiration pneumonia [32,33]. The gingival crevice, a deep but small space between teeth and gingiva, serves as an extremely low oxygen environment for anaerobic bacteria, some of which are potent periodontal pathogens. *Porphyromonas gingivalis*, *Bacteroides* species, *Fusobacterium nucleatum*, *Eikenella corrodens* *Aggregatibacter actinomycetemcomitans* have been cultured from infected lung fluid [33]. Data that the incidence of aspiration pneumonia is higher in dentate elderly than in edentulous elderly [34] support the pathogenicity of anaerobes in the gingival crevice for aspiration pneumonia. It is, however, noted that Marik et al. [35] could isolate only one anaerobe, *Veillonella parvula*, from 207 patients with ventilator-associated and aspiration pneumonia. *V. parvula* has not yet been confirmed for its pathogenicity to humans.

Aspiration pneumonia is caused by potent respiratory pathogens as well as oral commensals, a member of dental plaque and periodontal pathogens. Respiratory pathogens, *Streptococcus aureus*, *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Pseudomonas aeruginosa* and *Serratia marcescens*, are often isolated from dental plaque in institutionalized elderly [24,27]. These respiratory pathogens have also been found on the tongue of residents of a nursing home [36]. Gram-negative bacilli, especially members of Enterobacteriaceae, have been isolated from patients with severe aspiration pneumonia [30] and those on a ventilator in an intensive care unit [37,38].

Prevention of Aspiration Pneumonia

Preventive measures for aspiration pneumonia must target and modify its risk factors. Preventive strategies employed so far can be classified into three major categories: 1) prevention of aspiration by improving impaired swallowing or dysphagia, 2) enhancement of host defense mechanisms, and 3) reduction of bacterial inoculum into the lower respiratory tract by suppression of oropharyngeal flora [39].

For management of dysphagia in the elderly, dietary modification and tube feeding are recommended; however, the effect of tube feeding is still unclear [11]. Sasaki and coworkers have attempted to improve impaired swallowing using pharmacological measures. Angiotensin-converting enzyme inhibitors have beneficial effects on the impaired swallowing reflex in the elderly by increasing substance P concentration [40]. Administration of levodopa improved the impaired swallowing reflex in patients with cerebral infarctions [41]. The addition of capsaicin to liquid or food stimulated the swallowing reflex [42]. Moreover, theophylline could improve the impairment of the swallowing reflex in the elderly [43].

Vaccination is the most common method to enhance host defense mechanisms against infectious diseases. To prevent aspiration pneumonia, influenza vaccine and pneumococcal vaccine have been employed. Gross et al. [44] analyzed several reports that evaluated the efficacy of influenza vaccine in elderly persons, and concluded that the vaccination reduced the risk of pneumonia. Simonsen et al. [45], however, could not correlate increasing vaccination coverage after 1980 with a declining mortality rate by surveying databases in the United States from 1968 to 2001. Jackson et al. [46] performed a retrospective cohort study with 47,365 elderly, and demonstrated that pneumococcal polysaccharide vaccine significantly reduced the risk of pneumococcal bacteremia, but the risk of hospitalization for pneumonia slightly increased. Although the effect of vaccinating the elderly in nursing homes or long-term care facilities is still controversial, Bardenheier et al. [47] emphasized the need for strategies to increase vaccination coverage in these populations.

Poor oral hygiene is one of the major risk factors of aspiration pneumonia. Aspiration of oropharyngeal contents often occurs even in healthy adults in deep sleep [21]. The host defense mechanism and inoculum size may influence the result. If the inoculum size is not sufficient, the patient would not demonstrate a sign of aspiration pneumonia even when aspiration occurs. To minimize the inoculum size, oropharyngeal microflora should be suppressed. Oral health care to improve the oral hygiene status is the most potent method to control oropharyngeal flora. Dental plaque and biofilms in gingival crevices are common causative agents of aspiration pneumonia, which can be reduced by oral health care. Control of dental plaque not only removes respiratory pathogens existing in biofilm, but also prevents the colonization of exogenous respiratory pathogens in the mouth region. Scannapieco et al. [25] showed that dental plaque may serve as a colonization site for exogenous bacteria which can hardly adhere directly to a tooth surface, and enzymes produced by microbes in dental plaque may modify glycoproteins on mucosal epithelium which result in the adhesion of exogenous bacteria. Effects of oral health care on the prevention of aspiration pneumonia will be discussed in detail in the next section.

Effectiveness of Professional Oral Health Care

Oral intervention to improve the oral hygiene status to prevent aspiration pneumonia is becoming common for high-risk populations, especially for those in long-term care facilities or in nursing homes [48-52].

Yoneyama and co-workers have been investigating the effects of oral health care for the elderly in nursing homes. They provided oral health care once a day and cleaned the mouth

with povidone iodine after each meal in the experimental group and compared to the control group without care [49]. As a result, febrile days did not improve; however, worsening of febrile days was prevented by oral health care. Their group divided 366 elderly into two groups, one received oral health care and the other did not [53]. During two-year follow up, pneumonia was diagnosed in 19% of patients who did not receive oral health care and 11% of those who received oral health care. The relative risk of developing pneumonia without oral health care compared to with oral health care was 1.67. They further investigated the effect of oral health care using 417 elderly patients, divided into two groups with or without oral health care [54].

Dentists or dental hygienists provided professional oral health care once a week, and nurses or caregivers cleaned the mouth with a toothbrush and some with povidone iodine. During the experimental period, pneumonia, febrile days and death from pneumonia decreased significantly in patients who received oral health care. This effect was observed both in edentate and dentate elderly.

Adachi et al. [55] evaluated the effect of professional oral health care in 88 elderly persons over a two-year period. Professional oral health care consisted mainly of mechanical cleaning. In patients who received oral health care, the ratio of fetal aspiration pneumonia and the prevalence of high fever were significantly lower than in patients without oral health care. Moreover, influenza was observed in 1% of patients with oral health care while in 9% of those without oral health care.

Although oral hygiene alone can not prevent respiratory infections due to aspiration, it can lower the incidence of aspiration pneumonia by reducing the inoculum amount in the lower respiratory tract, and by inhibiting the colonization of opportunistic pathogens in the oral region.

Improving the oral hygiene status by oral health care not only reduces respiratory pathogens in the oral region, but also improves the cough reflex [56] and increases substance P concentration in the respiratory tract [57], which may prevent aspiration pneumonia.

Despite accumulating data that oral health care is effective for preventing aspiration pneumonia, it should be noted that several reviews have raised questions about the efficacy of oral health care [58,59]. Loeb et al. [58] searched for reports about the prevention of aspiration pneumonia and concluded that insufficient data exist to determine the effectiveness of oral hygiene as well as positioning strategies, modified diets, feeding tube placement, or delivery of food in preventing aspiration pneumonia. Terpenning [59] stated that there is low-level evidence supporting the use of oral health care for reducing aspiration pneumonia among elderly persons.

Further studies are needed to provide high-level evidence to support the effectiveness of oral health care for preventing aspiration pneumonia in the elderly. It seems likely, however, that oral health care intervention to prevent aspiration pneumonia is the least costly as well as the most effective to improve the quality of life of the elderly, especially those in nursing homes [59].

Effect of Professional Oral Health Care on Pharyngeal Microflora

To evaluate the effect of oral health care from a microbiological point of view, the collection point of samples is important. Abe et al. [50] sampled patient saliva, and investigated the changes in the oral hygiene status, microbial cell number and febrile days during oral health care intervention. Bahrani-Mougeot et al. [60] and Sumi et al. [36] collected samples from the tongue surface for bacterial determination. It is clear that mechanical or chemical cleaning of the mouth region reduces microbial numbers in dental plaque, in saliva or on the tongue. The pharyngeal region is closer to the lower respiratory tract and its microflora are affected by oral microflora [26]. We therefore planned to collect samples from the pharyngeal region by swabbing, where there is likely a direct source of microbes to be aspirated into the lower respiratory tract, and evaluated the microbial effect of oral health care.

First we performed a pilot study to assess the effect of oral health care on pharyngeal microflora with a smaller number of elderly in a nursing home [61]. After oral health care by dental hygienists, mainly by mechanical cleaning, for five months, the numbers of total culturable bacteria and streptococci isolated from the pharyngeal region by swabbing significantly decreased in the oral health care group. The number of staphylococci also significantly decreased after three months of oral health care.

On the basis of data obtained in the previous study, we evaluated the effect of oral health care on pharyngeal microflora with a larger number of elderly in nursing homes [62]. Intervention in oral health care was performed in three nursing homes for the dependent elderly in Hamamatsu, Japan. Thirty elderly in each facility, who had no history of antibiotic use within the preceding six months, were randomly selected for bacteriological examination. Among these 30 elderly, 24, 24 and 19 in facility A, B and C, respectively, completed bacteriological examination throughout the study. In facility A, the residents received professional oral health care by dental hygienists once a week for 5 months. In facility B, the residents received no oral health care for the first 2 months, followed by intervention once a week by dental hygienists for 3 months. In facility C, the residents cleaned their mouths with povidone iodine gargling once a day after lunch for the first 2 months, followed by additional oral health care once a week by dental hygienists for 3 months.

Pharyngeal bacterial samples were collected from the palatoglossal arches by swabbing four times with a sterile cotton bud. The swab was diffused into sterile diluting medium and then inoculated onto each medium using a spiral system. The media used were as follows: a brain heart infusion agar plate for total bacteria and black-pigmented species, a mitis-salivarius agar plate for *Streptococcus* species, a mannitol salt agar plate for *Staphylococcus* species, a CHROM-agar *Candida* plate for *Candida* species, and a NAC agar plate for *Pseudomonas* species. Plates were incubated under the appropriate conditions for each medium, and resulting colonies were counted and colony-forming units (CFU) calculated. Data were expressed as the mean CFU of residents explored for total bacteria and *Streptococcus* species, and by the incidence for *Staphylococcus*, *Pseudomonas*, *Candida* and black-pigmented species. Black-pigmented colonies were considered to include periodontopathic species.

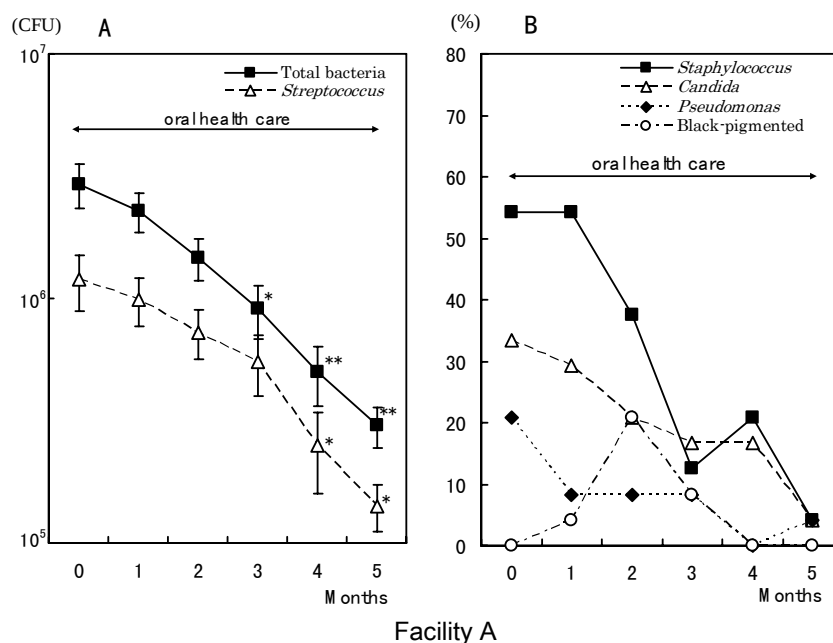


Figure 1. Changes in pharyngeal microflora of the elderly in facility A. A: CFUs of total bacteria and *Streptococcus* species, B: incidence of respiratory pathogens. Residents received oral care by dental hygienists for 5 months. Error bar represents the standard error of the mean. *: $p < 0.05$, **: $p > 0.01$ when compared with the beginning.

Figure 1 shows the change in pharyngeal microflora of the elderly in facility A during five months of oral health care. As shown in Figure 1A, CFUs of total bacteria and *Streptococcus* species decreased throughout the intervention period and the difference to initial CFU was significant after 4 months. Five months of oral health care suppressed both CFUs to almost 1/10 of the initial value. The incidence of respiratory pathogens, *Staphylococcus*, *Pseudomonas* and *Candida*, decreased gradually by oral health care and reached almost zero after 5 months (Figure 1B). The incidence of black-pigmented species increased slightly at 2 months; however, it decreased again at 5 months.

The results for facility B, where no oral health care was administered for the first 2 months as a control, followed by 3 months' intervention by dental hygienists, are shown in Figure 2. CFUs of both total bacteria and *Streptococcus* species did not change significantly during the 2-month control period, but had decreased by the start of oral health care, and significant reduction was observed after 4 months (Figure 2A). Although the incidence of 4 respiratory pathogens rose and fell during the control period, it started to decrease after the beginning of intervention and became less than 10% at the end of the study (Figure 2B).

In facility C (Figure 3A), povidone iodine gargling reduced total bacteria while it had no effect on the *Streptococcus* species. Additional intervention by dental hygienists enhanced the reduction of the bacterial number of both total bacteria and *Streptococcus* species. Povidone iodine gargling alone had almost no effect on the incidence of respiratory pathogens; however, additional oral health care reduced the incidence of *Staphylococcus*, *Candida* and black-pigmented species (Figure 3B).

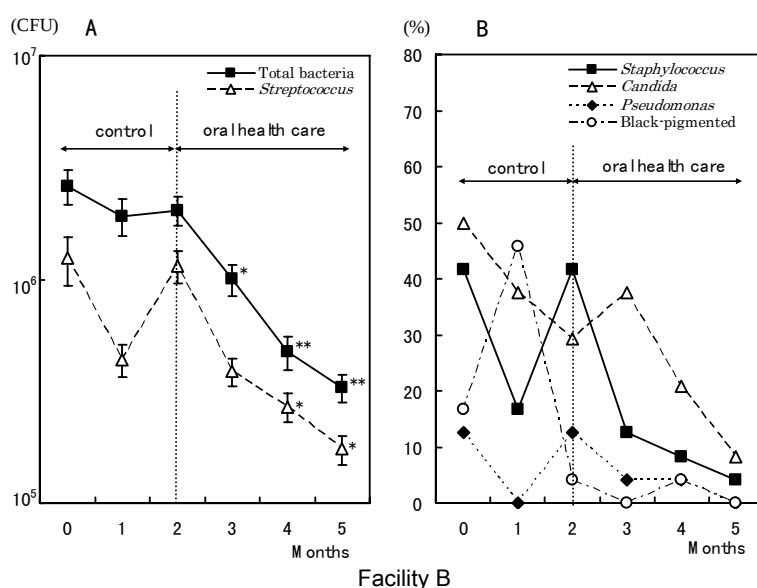


Figure 2. Changes in pharyngeal microflora of the elderly in facility B. A: CFUs of total bacteria and *Streptococcus* species, B: incidence of respiratory pathogens. Residents received no oral care for the first 2 months followed by oral intervention by dental hygienists for 3 months. Error bar represents the standard error of the mean. *: $p < 0.05$, **: $p > 0.01$ when compared with the beginning.

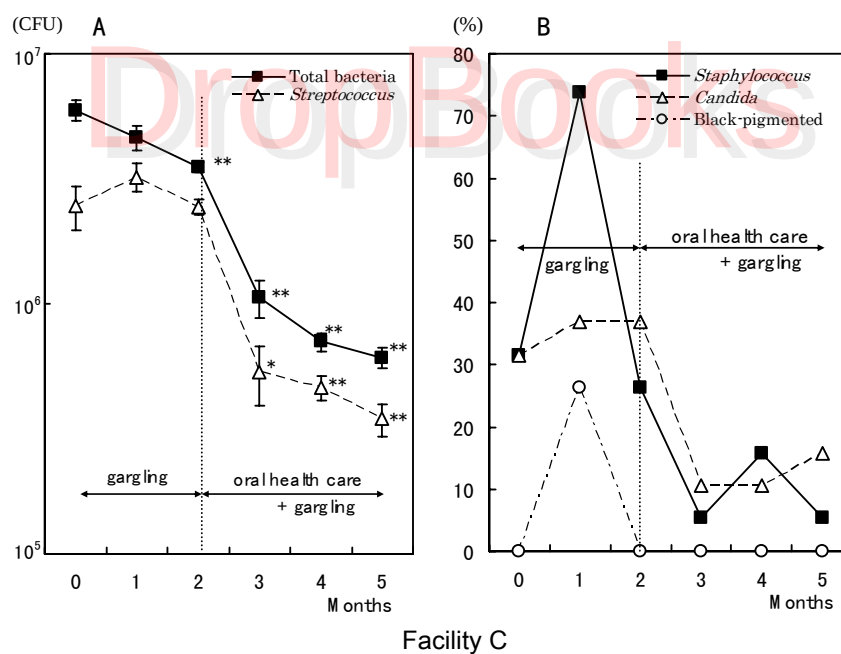


Figure 3. Changes in pharyngeal microflora of the elderly in facility C. A: CFUs of total bacteria and *Streptococcus* species, B: incidence of respiratory pathogens. Residents cleaned their mouth with povidone iodine gargling once a day for the first 2 months, and received additional oral care by dental hygienists for 3 months. Error bar represents the standard error of the mean. *: $p < 0.05$, **: $p > 0.01$ when compared with the beginning.

The results obtained in this study suggest the efficacy of improving the oral hygiene status by dental hygienists, mainly using mechanical procedures, on pharyngeal microflora, which might be a direct source of the pathogens aspirated to the lower respiratory tract. The effect to preventing aspiration pneumonia was not proved in this study, since a control group who received no oral health care throughout the study was not set up for ethical reasons. This study, however, provides a microbiological background for oral health care and may promote the practice of oral health care to prevent aspiration pneumonia.

Oral Health Care for Perioperative Patients and Those in Intensive Care Units

Improvement of oral hygiene status to prevent respiratory infections was also applied to patients undergoing surgery and those staying in intensive care units.

Although the efficacy of improving the oral hygiene status by oral care for preoperative patients is still controversial, the procedure can reduce respiratory pathogens in the mouth region, and is recommended to prevent postoperative infections [63,64]. Ohnishi et al., together with doctors and nurses, performed professional oral health care for preoperative patients receiving endotracheal anesthesia at Ikeda City Hospital, and patients with a fever of 38°C or above and the number of hospitalized days after operation decreased (Ohnishi T, personal communication).

The mouth of patients in intensive care units was also colonized by respiratory pathogens [37], especially by aerobic Gram-negative bacilli [38], and oral care has been attempted to prevent pneumonia. Koeman et al. [65] and Fourrier et al. [66] decontaminated the oral region with chlorhexidine and could suppress oral microflora; however, the efficacy to prevent pneumonia was limited. Mori et al. [67] provided oral care for patients in intensive care units with a ventilator by means of mechanical and chemical procedures, and reduced the number of pathogenic bacteria, especially *Pseudomonas aeruginosa*, and could lower the risk of pneumonia.

Conclusion

Aspiration pneumonia causes significant morbidity and mortality among elderly persons in nursing homes. To prevent aspiration pneumonia, several methods have been attempted to improve each risk factor for this disease. Poor oral hygiene is one of the major risk factors, and improving the oral hygiene status has been reported to be effective to prevent aspiration pneumonia. Although the efficacy of oral health care is still controversial, accumulating evidence supports its efficacy for preventing aspiration pneumonia. Oral health care, especially mechanical cleaning by dentists or dental hygienists is recommended to achieve a high quality outcome. Further studies, of course, are needed to investigate the etiology of the disease and to develop better preventive measures for the elderly.

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Chapter 16

Patient Autonomy and the Doctor-Patient Relationship in Dentistry: A Review of Research

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It is widely recognized in medicine that how physicians and patients communicate with each other can have a strong impact on patients' adjustment and response to treatment. Good communication and informed decision making likely promote better health outcomes and are regarded as intrinsic components of good quality care. [1,2] The present paper summarizes the present status of research on the physician-patient relationship and then examines available findings on patient-doctor interactions in dental settings.

The Physician-Patient Relationship

Empirical research on the physician-patient relationship began in earnest in the 1950s. It has accelerated in recent years with much of the impetus coming from the growing emphasis in medicine on finding ways to implement "patient-centered" models of health care. Such models, in contrast to the traditional "paternalistic" model of patient care, propose that patients need to be fully informed and actively participate in decision making regarding their own health care. [3] Increasing patient autonomy is said to not only be congruent with legal mandates, but also ethically correct in terms of adjusting the power asymmetry between doctors and patients. A wide range of empirical findings also indicate that increasing patients' involvement will likely positively affect their emotional adjustment, quality of life, disease course, and perhaps even survival and mortality. [4] However, it is recognized that in order for patients to be actively involved in their own care, effective two-way communication with their physician is required. Congruent with the biopsychosocial model of patient care, this communicative process involves not just a sterile exchange of information but also has

strong interpersonal and affective components. During medical consultations patients want to know what is wrong, what is causing their illness, whether and how it can be treated; secondly, they want to feel that they have a personal relationship with their physician (“the need to know and understand” and “the need to feel known and understood”). [5] Analogously, physicians’ communications during medical consultations have been conceptualized and measured in terms of both instrumental-task behaviors that are oriented around the doctors’ expertise in diagnosis and treatment (task communication) and affective/socioemotional behaviors that establish interpersonal relationships with patients (affective communication). [6] Considerable research has examined the role of both sets of variables on patient outcomes.

Task Communication

The concept of physician task-related behaviors has come to subsume two related sub-categories: (a) the extent to which physician display of expertise, competence, and mastery induces a sense of confidence in the patient that he/she is receiving high level care, and (b) the extent to which the physician involves the patient, shares disease- and treatment-relevant information, and elicits the patient’s input while embarking on a choice of treatment. Available research has shown that the former component has not been an issue for most patients; patients generally are satisfied with the quality of the health care they receive. They are however frequently dissatisfied with the communication accompanying that care. [7] Much of this dissatisfaction involves lack of information sharing and absence of a sense of mutuality. Most patients want more information and to a lesser extent want more active involvement in treatment decision making. [8] But in clinical practice patients play a largely “passive role” with their physicians [9] and physicians are reluctant to share responsibility with patients. [10] It is widely agreed that more balanced partnerships are needed between patients and physicians, and there is evidence that patients respond positively when offered choice of treatment or are encouraged to negotiate decisions with their physician. [4] However, there is increasing recognition that increased responsibility may not be suitable for all patients.¹¹ Some patients (older, sicker, less educated; African-Americans and Hispanics) prefer lower levels of participation and may respond poorly if this is thrust upon them. [12,13] Other data indicate that more involvement may produce decisional conflict [14] or induce anxiety and self-blame, especially if outcomes are below expectation. [15,16] Thus, some patients prefer dominant and controlling doctors in the traditional paternalistic mode, whereas others do not. [8] It has therefore been suggested that doctors should tailor involvement to patients’ desired level of control rather than aim for overall increased patient participation.¹¹ Two strands of research support this contention. It has been found that concordance of involvement beliefs in doctor–patient pairs – similarity in preference for patient-centered versus doctor-centered, or egalitarian versus authoritarian physician roles – has led to greater patient satisfaction and to greater adherence to medical regimens. [11] This is especially the case for pairs which are concordant about the value of patient participation. Second, evidence is strong that patient psychosocial adjustment to treatment is better and post-treatment dysphoria is lower when level of information received by patients matches

their preference. [11] Relevant research in this area involves assessment of the effects of giving patients different levels of information on patient adjustment, satisfaction, and other outcomes. In the area of decision-making involvement, physician-patient mismatches are most frequent for patients enacting less participation than desired; evidence on patient outcomes (though more variable) also favors the matching hypothesis [11].

Affective-Socioemotional Communication

Comprehensive literature reviews have documented that high-quality doctor-patient relationships (defined largely on the basis of physician affective behaviors): (a) generally produce positive patient outcomes, (b) improve patients' biological/physiological disease status, (c) enhance patients' psychological adjustment to the disease and reduce emotional distress, (d) build trust, (e) increase patients' satisfaction with medical care, (f) enhance information recall by patients, (g) enhance patients' compliance with medical advice and treatment, (h) increase physicians' satisfaction, (i) facilitate the process of diagnosing medical conditions, (j) affect medical management decisions, (k) reduce the frequency of patients' pursuit of malpractice suits, and (l) reduce the frequency of patients' decisions to change physicians. [7,17] A weakness in arriving at definitive conclusions about which particular physician behaviors are most essential is the large number of communication process variables that have been measured by researchers and the multiple coding systems that have been used to operationalize them.

Kiesler and Auerbach [17] argue, based on interpersonal theory and prevailing circumplex models of interpersonal behavior, that the two cardinal dimensions of interpersonal behavior are control (dominance-submission) and affiliation (friendliness-hostility). These dimensions have been consistently noted by medical interaction analysts as prominent communication styles displayed by physicians during consultations [18,19] and they coincide with conceptual models identifying the essential aspects of the affective care component of physician behavior. Research on physician-patient communication has found that patients generally experience positive outcomes (satisfaction with care, some primary medical outcomes) after interacting with physicians whose behaviors are high in affiliation and low in control. [17] But virtually all of these studies have limited their measurement of control and affiliation to behavioral codings of the physician's behavior. Relatively few have measured the patient's behavior as well or have obtained data on the patient's view of the physician's behavior. There are few studies of how physician behaviors are interpreted by patients and available findings indicate little agreement between patients', physicians', or observers' perceptions of the physician-patient relationship.

Complementarity is the central principle in circumplex models of interpersonal behavior. [20] On the interpersonal circumplex, complementarity occurs on the basis of correspondence on the affiliation axis (friendliness evokes friendliness, hostility evokes hostility) and reciprocity on the control axis (dominance elicits submission, submission elicits dominance). Available research conducted in a range of medical settings (mostly primary care) has produced promising findings. Patient-doctor pairs have been most frequently found to be similar in affiliation, with both participants showing friendliness and cooperation, and

contrasting in control, with doctors more frequently dominant and patients more submissive. Further, recent studies have provided some support for the hypothesis that interpersonal complementarity between doctor and patient (consistency on the affiliation dimension, divergence on the control dimension) is associated with positive patient outcomes. [17] Auerbach et al. [21] found that diabetic patients' metabolic control (glycosylated hemoglobin-HA_{1c}) was worse when there was poor complementarity between physician and patient on the control dimension. Auerbach et al. [22] found that doctor-patient complementarity was associated with greater patient satisfaction with and adjustment to an invasive oral surgical procedure. Other investigators have found that affiliative behavior on the part of both patient and their physician was associated with greater satisfaction in primary care patients [23,24] and in diabetic patients, [25] and that less physician control in conjunction with more control by patients was related to a range of positive outcomes in ulcer, hypertensive, and diabetic patients and to diminished experience of symptoms in breast cancer patients in the periods between cycles of adjuvant chemotherapy [26].

The Doctor-Patient Relationship in Dental Settings

Research on issues of patient autonomy and issues pertaining to the practitioner-patient relationship has been far more limited in dentistry than in medicine. However, there has been recognition by dental practitioners that this area needs to be addressed. Further, there has been work on conceptualizing the dentist-patient relationship, some empirical work measuring the dentist-patient relationship, and programs have been developed aimed at both modifying and improving dentists' interpersonal skills and at enhancing patient participation and autonomy.

Dentist Affective Communication and Patient Response to Treatment

Several studies conducted in a wide range of dental settings have affirmed the importance of dentist communication to patient response to treatment. Corah et al. [27] found in a study of 231 adult general dentistry patients that patients' perception that the dentist was accepting and caring was the variable that contributed most to patient satisfaction. In a follow-up study of 250 adult patients Corah et al. [28] reported that patients' ratings of dentist friendliness, and the degree to which they gave moral support was associated with lower anxiety, and ratings of dentists' empathy and communicativeness was associated with patient satisfaction. Murray et al. [29], Schouten et al. [30], and Rouse and Hamilton [31] obtained similar findings in samples of 78 craniofacial pain patients, 90 Dutch dental emergency care patients, and 236 undergraduates reflecting on their most recent visit to the dentist respectively. Mellor and Milgrom [32] found that, in a sample of 289 dental surgeons in general practice in England, assessment by the dentist of lack of communication with patients was significantly associated with the incidence of malpractice complaints by patients to insurers.

Other investigators have evaluated more specific components of the communication process and examined their relationship to patient outcomes. Oates et al. [33] found that among 188 patients who had received extensive restorative treatment, satisfaction with the provider-patient relationship was positively related to deciding to have extensive restorative treatment and had the greatest influence on the likelihood of treatment. Perceptions of relationship included perceptions of shared responsibility, friendliness, being encouraged to ask questions and being told enough to make a good decision. Street [34] surveyed 572 general dentistry patients of 17 dentists. Consistent with comparable findings in medical settings, he reported a strong positive relationship between patients' perception of communicative involvement (extent to which the dentist appears attentive, perceptive, and responsive to the patient's comments and needs) and patients' satisfaction. There was a moderate negative relationship between perceptions of the dentists' dominance (degree to which the dentist disagrees, is argumentative, and controls the nature and topics of the encounter) and patient's satisfaction. In addition, satisfaction of patients seeing the dentist for the first time versus those on repeat visits was more strongly influenced by their perception of his communicative involvement. This was interpreted as being a function of the fact that patients with no prior experience with the dentist rely more on how he treats and talks to the patient in assessing the quality of care received than repeat patients.

Auerbach obtained findings largely consistent with those of Street in three studies with dental surgery patients and one with denture patients. All studies used the Impact Message Inventory-IMI, [35] a validated measure based on the circumplex model of interpersonal behavior, to evaluate patients' subjective impressions of doctors. Auerbach et al. [36] in a sample of 47 patients who had sustained traumatic maxillofacial injury requiring emergency treatment, found that patients who appraised the doctor as more controlling and dominant during their first post-surgical consultation had higher levels of acute stress disorder. In a study of 30 patients evaluated before and after undergoing orthognathic surgery, Auerbach et al. [37] found that patients' perception of the surgeon as "hostile" was predictive of poorer adjustment just after surgery and perception of the surgeon as "friendly" was predictive of better self-esteem four months after surgery. Similar findings were obtained in a study of 102 denture patients [22] which found that patients' perception of dentists as dominant and unfriendly was associated with poor patient satisfaction with dentures and poor adjustment during treatment respectively. In a study with 40 dental extraction patients, Auerbach et al. [38] had information about the impending extraction presented to patients pre-operatively either in a warm, personal fashion or a relatively cold impersonal fashion using non-verbal cues. The non-verbal cues that were manipulated were the number of smiles, extent of eye contact, voice tone (variable, enthusiastic vs. monotonous, flat), body orientation (direct, open vs. angled, closed), body lean, and hand movements (emphasizing content vs. interruptive, rubbing of eyes). Patients for whom information was delivered in an impersonal fashion perceived the information giver as more dominant, more hostile, and less friendly. Further, the degree to which patients viewed the information giver as dominant, submissive, friendly, and to a lesser extent hostile, generalized to patients' subsequent perception of the dental surgeon. Patients' perceptions of dominance and hostility were negatively associated with independent ratings of how well they adjusted during surgery (in terms of fear response to anesthesia, anxiety displays, uncooperativeness, and admission of pain). The findings

indicated that patients are sensitive to the behavior of members of the healthcare team who are not primary service providers, in addition to the behavior of the dentist or physician. This is significant because patients often spend a good deal of their time with these service providers, often receive much of their information from them and sometimes interact only briefly with the physician or dental surgeon.

Studies conducted in medical settings tend to rely on behavioral ratings to evaluate interpersonal behaviors. Sondell and colleagues, in contrast, are one of few dental investigators to obtain independent behavioral ratings of patients' and dentists communicative and relationship behaviors, rather than relying solely on subjective self-reports of interactants. In their research, patient and dentist behaviors were rated using a dental adaptation of the Roter Interaction Analysis System (RIAS), [39] a coding system that classifies patient and healthcare provider communications into small verbal units and which has been widely used in medicine. Using the RIAS, Sondell et al. [40] in a study of 61 prosthodontic patients and 15 dentists, present some of the limited data available on the nature of dentist-patient communications during the office visit. They found that dentist-patient communication contained more task-focused than affective-socioemotional behaviors and that female patients used socioemotional talk to a greater extent than male patients. Dentists and patients of different genders communicated more overall, especially male dentists with female patients. In a second set of data analyses, Sondell et al. [41] found that patients were more satisfied when there was more personalized socio-emotional communication, which resulted in more question asking by the patient. Patients were less satisfied when task-focused communication oriented around dentist information gathering and impersonal talk and instructions was more frequent.

Other than the dental adaptation of the RIAS, only one other behavioral rating scale was located that was specifically designed to provide a measure of communication in the dental setting. Newton and Brenneman [42] describe a behavioral rating scale oriented around three identified phases of the dental consultation: opening or introductory phase (e.g., patient greeting, establishing rapport, identifying patient's problems), examination and treatment (e.g., putting patient at ease, identifying and clarifying the patient's problem, discussing treatment options, confirm patient's understanding of information), and closing phase (e.g., summarize consultation, confirm patient's understanding). It thus focuses on the dentist's behaviors and primarily surveys task-oriented behaviors, although some affective behaviors are also included. Other than Schouten et al.'s study with emergency care patients³⁰ no studies were uncovered using this measure, however it could provide valuable information especially when used in conjunction with more refined rating scales of fine-grained behaviors (e.g., RIAS) or subjective appraisal measures of interpersonal behavior (e.g., IMI).

Promoting Affective-Interpersonal Skills in Dental Practitioners. There have been numerous studies evaluating the effects of training programs designed to improve practicing physicians' interpersonal-affective skills. In addition, since the early 1990's all medical schools have offered some type of communication skills training and structured training programs are increasingly becoming part of medical school as well as residency training curricula. [43] No reports of training programs designed specifically for dental practitioners were uncovered. However, there appears to be growing emphasis on teaching interpersonal and communication skills to dental students, with formal programs becoming increasingly

integrated into the dental school curriculum. For example, Wagner et al. [44] describe a program implemented at the University of Connecticut in the junior and senior years using patient-instructors (PIs). PIs are usually teachers, actors, and health care professionals “trained extensively to portray a fictional patient with a specific history and presentation and to evaluate student performance in interpersonal skills---.” Student interviews with PIs (and opportunities to practice counseling skills) involve increasingly more complex dental encounters (starting with basic interviewing skills and moving to situations such as smoking cessation, substance abuse, belligerent patient behavior and non-compliance) as they progress in their dental training. Students receive individual feedback, and if necessary remediation consisting of review of videotapes of encounters with faculty. Overall, students were found to improve over time with performance best during final rotation. Broder and Janal [45] have also reported significant positive changes in interpersonal communication skills in a similar dental school training program using PIs, and in another program Hottel and Hardigan [46] reported similar positive changes in interpersonal skills in dental students in a training program involving recognition and modification of patient anxiety, interviewing techniques, patient records, behavior management, and patient relations.

Task Behaviors: Patient Information Seeking and Involvement in Decision Making

As noted above, an important component of patient-centered models of health care is the concept that patients need to be fully informed and participate interactively with their doctor in decision making regarding their treatment and care. Although this area has come to be of prime concern in medicine less attention has been paid to it in dentistry.

Patient Information Seeking and Desire for Information. Schouten and colleagues have examined information seeking in both emergency care and regular dental patients. In one study [30] they observed that emergency care patients did not engage in a lot of information seeking behavior nor did they seem to desire active involvement in choice of treatments. Similar findings were obtained in a study [47] of 96 emergency and 245 regular patients both of whom exhibited high preferences for information but significantly lower preferences for actual involvement. These findings are similar to those that have been obtained consistently with medical patients in a wide range of settings [8].

Some studies have measured individual differences in dental patients' desire for information and other personality characteristics, and have evaluated the effect these differences have had on how patients responded to high information vs. low information interventions. Auerbach et al. [48], prior to third molar extraction surgery, exposed some patients to a brief videotape which gave them specific information about their impending surgery (conditions that result in people becoming candidates for surgery, the procedures that the dental surgeon would engage in, accurate expectations regarding pain and discomfort they would experience, and what they could expect post-operatively in terms of pain and swelling and what they would be able to do about it). Other patients were randomly assigned to an attention-placebo general information videotape which gave them information only marginally relevant to their impending surgery. Patients' adjustment and behavior during the

dental procedure was independently rated by dentist observers. It was found that overall the two different levels of information exposure had no significant effect on patient adjustment levels. However, prior to their surgery patients had been administered an indirect measure of their desire for information (locus of control orientation). Patients who were internal in locus of control (those who felt that in general they could actively control important personal outcomes) adjusted much better when they received specific vs. general information beforehand, whereas those who were external in locus of control (those who believed that important personal outcomes are largely due to chance and not personally controllable) responded better when they received the general information. A second study with third molar extraction patients³⁸ followed up on this study and confirmed the finding that patient preferences need to be taken into account in determining how patients will respond to different degrees of information about their condition and the treatment procedures the dentist will undertake. The findings of these studies indicate that patients do not uniformly respond well to high levels of information, and are consistent with the current emphasis that matching patient information and decision making involvement with their preferences will maximize patient outcomes [11].

Patient Involvement in Decision Making. As noted above, “shared decision-making” is one of the cornerstones of the concept of patient-centered medicine. However, although medical patients tend to say that they want a lot of information their stated desire for input into decision making is skewed more in the direction of physician-only or at least collaborative decision making. [8] The question of shared decision making has received relatively little attention in the dental literature. However, in a recent study of 40 patients from a general dentistry practice Chapple et al. [49] obtained patient preference findings consistent with those obtained from the many studies with medical patients. Using a dental adaptation of the Degner Control Preferences Scale, [50] they found that patients favored a collaborative decisional role (with patient and dentist equally sharing responsibility for decision-making), or that they deferred to their dentist rather than take an active role in their own treatment. However, (similar to the findings of Schouten et al. [51] in a study of emergency dental care patients) patients typically viewed themselves as attaining a passive role in treatment decisions regardless of their preferences. Patients attributed the latter to a lack of knowledge about dentistry and trust in the dentist.

Although it has been observed that patients comply better if the dentist allows them to act as an equal partner during the encounter, [40] there have been few studies examining the effects of shared or enhanced decision making participation on dental patient outcomes. One of the few available studies [52] evaluated the effects of providing endodontic patients with a decision aid. Patient decision aids “are adjuncts to counseling that explain options, clarify personal values for the benefits versus harms, and guide patients in deliberation and communication.” [53] Among the media used in decision aids are decision boards giving probabilities of outcomes and side effects associated with different treatment procedures, in addition to interactive videodisc presentations and information presented via CD-ROM, audiotapes and booklets. [53] Decision aids for medical patients, in comparison to usual care, have been found to perform better in patient knowledge, stimulating patients' active involvement in decision making, and lowered decisional conflict, but have had little effect on patient satisfaction with decision making, anxiety, and primary health outcomes. [54]

Johnson et al. [52] developed and tested an endodontic decision board for chairside use to help clarify treatment alternatives, benefits, risks, prognosis, and costs when root canal therapy or extraction of a tooth was indicated. Similar to findings with medical patients, patients using the decision board demonstrated a small, but statistically significant, increase in knowledge compared to patients given usual care, but there was no difference between groups on measures of satisfaction or anxiety.

Two studies that evaluated the effects of giving dental patients actual choices during treatment obtained inconclusive findings. Auerbach et al. [22] assigned 102 denture patients either to a decisional control group, a no decisional control group, or to a treatment as usual group. Patients in the decisional control group were presented audiotapes giving detailed information and emphasizing the importance of them taking responsibility for expressing their preferences and making suggestions. During treatment they were asked to make decisions about the size, shape, and color of teeth to be used, and the color of the material in the dental base, and were asked to make suggestions regarding fitting and final adjustments. Patients in the no decisional control group listened to the same informational tapes, but it was emphasized that the dentist was in control and would take responsibility for their comfort and the accuracy of the procedures. Further, the dentist made the decisions about the teeth and any adjustments during the fitting procedure without consulting the patient. Contrary to expectation, no main effects for the control manipulation were obtained and interactions between experimental conditions and control-related patient individual difference variables were not consistent with previous findings. In a similar study with a small sample of oral surgery patients, Frantsve [55] also found that giving patients choices (e.g., type of anesthesia, type of music played during surgery, the side of the face they wanted extractions to begin on) had no effect on patient outcomes (adjustment during surgery, satisfaction, recovery from surgery).

Summary and Conclusions

As a consequence of increasing respect for patients' autonomy the practice of medicine has become less authoritarian and more patient-centered. Research in medical settings indicates that patient satisfaction and other outcomes tend to be linked to friendly and non-dominant physician interpersonal behavior, information provision by doctors, and to more active patient participation in their own care. Because of these developments, physicians increasingly feel pressured to adopt a more egalitarian and participatory role during consultations with their patients. The concept of patient empowerment [56] and the need to establish effective doctor-patient communication [57] has been addressed in dentistry but has not produced the same level of interest or concern as in medicine, and there does not appear to be as much pressure on dentists to adopt a more participatory role during consultations with patients. The relevant research literature in dentistry is sparse compared to the voluminous literature in medicine, [see 7,11,17] and whereas there have been numerous studies evaluating communication training programs for practicing physicians [43] there have been few if any for dentists (although programs teaching communication skills are being increasingly integrated into dental school training programs).

Based on the available research many of the findings in the two settings are comparable. As in medicine, better dentist-patient relationships are associated with better patient outcomes. Like medical patients, dental patients say they want a lot of information but are somewhat less inclined to become actively involved with the dentist in treatment decision making. Although most patients say they would like to be fully informed there are individual differences in this regard, and in both settings the more the information received by patients matches their preferences the more they are satisfied and the better their adjustment to treatment. Studies encouraging patient assertiveness, choice and active involvement in decision making in medicine have produced some encouraging findings, [4,43] but the few studies conducted with dental patients have been inconclusive. Clearly more research of this type in dentistry is warranted, particularly studies that evaluate how patients who differ in their preference for participation in decision making respond when given opportunities to participate.

It has been concluded that level of patient participation in the typical medical practice setting is "out of step with ethical ideals." 10 The extent to which this is true in the typical dental practice setting has not been established. However it appears prudent to continue to investigate ways to improve dentist-patient communication, and to give patients who desire to be highly informed and to participate with their dentist in determining treatments the opportunity to do so.

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Short Communication A

The Importance of Pre-Extraction Radiographs

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Introduction

Tooth extractions are considered routine procedures in many dental practices. As such, clinicians may become complacent when performing them, especially when patients arrive as emergencies in the middle of a busy day. However, caution, care and good pre-extraction records are advised for every case, as complications may arise when least expected.

Although a knowledge of normal root anatomy is mandatory, pre-extraction radiographs are still essential to detect the more rare abnormalities. They have other advantages including: identification of pathology within the tooth itself or the surrounding tissues; evaluation of an area that is not clinically visible; assessing tooth vitality; identification of root numbers; anatomical orientation of the roots; and as an aid in treatment planning [1]. However, being two-dimensional, they have limitations and may not reveal divergent roots in multi-rooted teeth, which will require different paths of withdrawal [2]. Post-extraction radiographs may be equally as important to confirm that all root fragments have been removed, especially in situations where there was previous periapical pathology. Infection from an abscess in a maxillary posterior tooth can spread into the maxillary sinus leading to a suppurative sinusitis, and in some rare situations or immunocompromised patients may even progress into an orbital abscess, with dire consequences [3].

Although fractured root fragments may become a nidus of infection, they may be left behind if there is no associated pathology or where there are potential dangers associated with their removal, including pushing of a root tip into the maxillary sinus, the mandibular canal or other buccal structures [4, 5]. However, the patient should be advised about their

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presence and encouraged to return for follow-up radiographs to monitor for any possible complications [2].

The following case illustrates the importance of pre- and post-extraction radiographs and record keeping.

Case Report

A 56 year old male patient presented with pain in the right maxillary quadrant. On clinical examination it was evident that he had a heavily restored dentition, thus a panoramic radiograph was taken (Figure 1). The 4 wisdom teeth had been extracted over 20 years before along with the 15. The 14 was root treated and appeared to have 2 root canals, of which only 1 was adequately filled. It was however asymptomatic. The 16 was grossly carious with a furcation involvement. The patient was not prepared to undergo another endodontic procedure to try and save the tooth and requested that it be extracted. After completing the examination and drawing up an appropriate treatment plan, the tooth was extracted. The clinician was confident that it had been removed in its entirety, and gave it to the patient who had requested to keep it.

The patient returned 2 weeks later complaining that “something was disturbing him when he ate and it felt as if there were hard pieces coming out of the socket”. He was informed that these were probably small fragments of alveolar bone that had been fractured off during the extraction process, and it was suggested that they be removed to help speed up the healing process. The clinician took an exploratory periapical radiograph and was dismayed to discover 2 remaining root tips (Figure 2), as he remembered the extraction being uneventful and he was convinced that he had examined the tooth to check for any signs of fracture.



Figure 1. Panoramic radiograph prior to extraction of 16.



Figure 2. Periapical radiograph two weeks after extraction of 16.

Unfortunately the patient had thrown the tooth away a few days previously so there was no way to confirm or dispute this. However the clinician was certain that he had not been negligent and went back to examine the patients records. He then discovered that on the initial panoramic radiograph there were two radiopacities in the periapical region of the 16. They did not look like roots of the 16 and were assumed to be isolated lesions as the roots of the 26 did not have any similar areas. The fragments were subsequently removed surgically and visual inspection confirmed that they were residual root tips (Figure 3).



Figure 3. (Continued).



Figure 3. Surgically removed residual root tips.

It was postulated that one of them may have fractured off from the 16 during its extraction or that both had infact remained after the extraction of the 15 many years previously. The patient had not been alerted to their presence by his previous dentist, and because they had remained asymptomatic, had gone undetected.

Discussion

Fractured roots tips in the maxillary premolar region are common because of the high incidence of bifid roots and root dilacerations in these teeth [4]. In a study by Pecora et al (1993) 90.3% of maxillary second premolars had one root and 9.7% two roots. However, 32.4% had two canals. Almost all of them had a distal root curvature regardless of root number [6]. Velmurugun et al (2007) reported on three rare instances where they found three roots with three separate canals in second premolars [7]. The incidence of two or three canals is higher in first premolars where Chapparo et al (1999) found that only 40.0% of teeth had one root, 56.7% had two roots and 3.3% had three roots [8]. They stressed the importance of a good knowledge of root and canal morphology, and the need for careful radiographic examination as part of competent extractions or root canal therapy in all maxillary premolars.

Cross-sectional computed tomography (CT) has been shown to provide a much more accurate picture of posterior roots than regular panoramic radiographs, especially as far as their lengths of protrusion into the sinus cavities [9]. Although expensive, a CT image may thus be warranted especially if later osseointegrated implant placement is anticipated as retained roots could lead to implant failure [4].

Conclusions

A successful extraction should result in complete removal of the tooth and its roots with minimal trauma to adjacent tissues [10]. To achieve this it is necessary for a clinician to have a good knowledge of tooth and root morphology, be equipped with and use the appropriate instruments and diagnostic aids, and to operate with care and patience.

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Short Communication B

A Simple Method to Ensure Sufficient Occlusal Reduction in Fixed Prosthodontics

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When preparing a tooth for a full coverage restoration (overlay, cast metal crown, porcelain jacket crown or porcelain-fused-to-metal crown) it is crucial to ensure that there is adequate occlusal reduction to accommodate the restorative material of choice. This ranges from 1-1.5mm depending on which material will be used. In addition, this reduction must be sufficient in both static and functional occlusion. The shape of the prepared occlusal surface should follow the general contours of the original tooth anatomy so that the created “space to restore” is evenly distributed, thus allowing the restoration to be of a uniform thickness [1]. At the same time removing a minimum amount of tooth tissue helps to keep the axial walls as long as possible for better retention [2]. The occlusion between opposing teeth should be checked before beginning the preparation, and subsequently rechecked during and after completion of the preparation until sufficient space has been created to accommodate the restorative material [2]. Failure to provide adequate clearance results in an over-sized restoration that will impinge on the inter-occlusal space. If cemented it will cause an open bite initially, and can lead to occlusal trauma. This may manifest as stresses on the tooth itself or the opposing dentition, temporomandibular joint pain, masticatory muscle spasms, chronic unexplained dental pain, dislodgement of the restoration, coronal fractures or a combination of any of these symptoms. There may also be radiographic evidence of periapical pathology and widening of the periodontal ligament with subsequent tooth mobility. The patient may experience difficulty making voluntary protrusive and lateral excursions when their teeth are

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in contact. Attempts at occlusal reduction invariably result in thinning, weakening or perforation of the restoration.

In order to avoid these adverse consequences various methods have been advocated to help the clinician verify whether there is adequate space available for the planned restoration. These include:

- a) Visual inspection of the preparation with the patient biting into centric occlusion, and whilst performing lateral movements of the mandible.
- b) Using a ball-ended burnisher to determine the amount of interocclusal space. The ball on the one end of this instrument has a diameter of 1mm, and is used when preparing a tooth for a cast restoration, while that on the other end is 1.5mm and suitable for determining clearance when porcelain-fused-to-metal is to be used (Figure 1).
- c) Preparing the provisional restoration before the final impression is taken. The thickness of the resin material can then be “eye-balled” (Figure 2) or measured with a caliper (Figure 3).
- d) Placing a piece of warmed pink baseplate wax (approximately 2mm thick) between the teeth and asking the patient to bite down. The tooth indentations are then inspected to detect areas where the wax has been perforated or become too thin.

All of the above methods have limitations and may pose difficulties clinically. Visual inspection is almost impossible in certain regions such as on palatal cusps of maxillary molars and lingual cusps of mandibular molars. A ball burnisher cannot be manipulated into all zones and will not detect the space available over the entire occlusal surface of the preparation, thus there could still be high spots that can go unnoticed.



Figure 1. Ball-ended burnisher with ball diameters of 1 mm used to check clearance of an anterior tooth preparation.

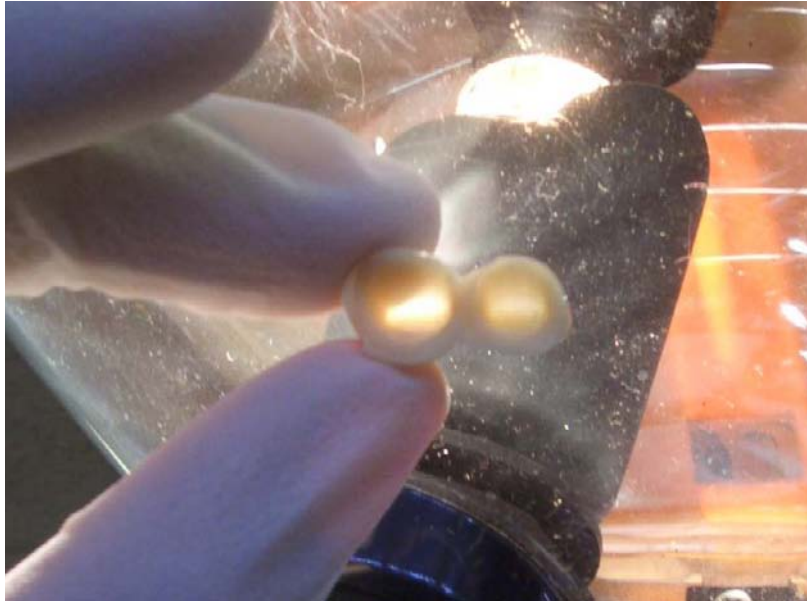


Figure 2. Gauging the thickness of a provisional restoration by holding it to the light.



Figure 3. Vernier calipers used to determine the thickness of the provisional restoration.

The provisional restoration may be a valuable indicator of what the final restoration will look like, but it is not always possible to gauge its exact thickness in all areas visually or with a caliper. Its dimensions may also be deceptive if it was made using a coping from a diagnostic wax-up. Calipers are more useful in determining the thickness of the final restorations, especially gold crowns which are approximately 0.5 mm thick, and thus easily perforated during occlusal adjustment.



Figure 4. Patient biting into baseplate wax with articulating paper on its uppermost surface.



Figure 5. Exact markings on the tooth where further reduction is needed.

Baseplate wax is one of the most reliable methods for determining the amount of tooth reduction over the entire occlusal surface, however it may be tricky trying to transfer information from the wax indentations to the exact sites on the tooth where further reduction is needed. A simple modification of the wax method²³ clearly indicates to the clinician the precise points on the tooth that still need to be cut down. A small piece of thin articulating paper (Hanel, Roeko, Germany) is pressed onto one surface of the baseplate wax. This wax-

²³ A 5th year dental student, Ms Buleni, suggested the technique presented in this article

paper union is then placed against the tooth being prepared with the paper side facing the cut tooth surface (Figure 4). The patient is then asked to close down and bite into the wax. High spots or areas that need further reduction will penetrate the wax and at the same time be marked by the paper. These are then easy to identify and reduce (Figure 5). The process can be repeated whilst the patient performs lateral excursions to ensure adequate clearance during both static occlusion and functional movements.

The operator is cautioned to not reduce the tooth excessively, by only cutting areas with a distinct paper marking on the occluding surface.

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DropBooks

Index

A

- abnormalities, vii, 172, 211, 213, 221, 230, 233, 243, 261, 262, 265, 373, 401
- absorption, 48
- academic performance, 31
- academics, 132
- accessibility, 337
- accidental, 153, 155, 164, 165, 170, 171, 180, 189, 252
- accidental injury, 165
- accidents, ix, 147, 148, 149, 152, 166, 178, 179
- accountability, 125, 140
- accounting, 201
- acculturation, 17
- accuracy, xi, 13, 19, 295, 306, 309, 315, 316, 317, 319, 321, 325, 326, 327, 328, 330, 331, 337, 395
- ACE, 383
- acetate, 154
- achievement, vii, x, 1, 3, 8, 11, 30, 199, 234, 256, 258
- acid, 39, 40, 54, 74, 97, 98, 99, 101, 102, 103, 105, 118, 156, 201, 261, 349, 352, 354
- acidic, x, 51, 71, 98, 99, 105, 199
- acidity, 44
- acidosis, 363
- Acinetobacter*, 164, 175
- ACM, 345
- acrylate, 98
- activation, 25, 59, 116, 283, 293
- activity level, 2
- acute, xii, 36, 38, 42, 46, 50, 56, 59, 74, 80, 104, 161, 167, 168, 181, 357, 359, 363, 365, 391
- acute infection, 42
- acute leukemia, 80
- acute myeloid leukemia, 365
- acute stress, 391
- ADA, 93, 121, 123, 124, 125, 127, 184, 194
- adaptation, 30, 116, 154, 209, 287, 392, 394
- adhesion, 74, 97, 98, 99, 105, 110, 112, 201, 291, 359, 365, 368, 375
- adhesion strength, 99
- adhesives, viii, 92, 97, 98, 100, 113, 156
- adiponectin, 354
- adjustment, xiii, 11, 274, 387, 388, 389, 390, 391, 393, 395, 396, 397, 398, 399, 409
- administration, 52, 54, 56, 58, 60, 82, 161, 168, 180, 359
- adolescence, 149, 152, 160, 264
- adolescents, viii, 22, 28, 29, 30, 33, 92, 110, 113, 114, 182
- ADS, 294
- adult, 26, 28, 29, 30, 43, 89, 94, 214, 283, 286, 360, 367, 369, 390
- adult population, 26, 89
- adulthood, 152, 264
- adults, x, 3, 4, 6, 26, 32, 34, 59, 113, 114, 182, 199, 260, 282, 287, 291, 294, 373, 375, 382, 383, 384
- adverse event, 350
- aerobic, 358, 380
- aerosol, 173, 195, 196
- aerosols, 55, 175, 182, 193, 194
- aesthetics, viii, 91, 108
- aetiology, ix, 147, 148
- Africa, 151, 363
- African-American, 388
- Ag, 75
- agar, 377

- age, 17, 22, 25, 28, 92, 96, 110, 141, 148, 151, 152, 157, 184, 185, 187, 209, 211, 213, 214, 217, 221, 223, 232, 233, 235, 249, 294, 358, 373
- agent, x, xii, 55, 59, 72, 99, 103, 107, 112, 114, 156, 164, 165, 167, 267, 268, 269, 271, 273, 347, 350, 358, 359, 360
- agents, x, xii, 6, 44, 45, 50, 52, 55, 65, 72, 75, 97, 113, 156, 164, 165, 166, 171, 177, 178, 180, 182, 184, 201, 267, 268, 269, 271, 347, 357, 374, 375
- aggression, vii, 1, 4
- aggressive behavior, 4
- aging, 22, 112, 291
- agonist, 55, 56, 84, 283
- agreeableness, 3
- aid, ix, 11, 127, 128, 147, 148, 157, 159, 334, 348, 394, 399, 401
- AIDS, 19, 20, 165, 170, 182, 188, 192, 194, 358, 359, 361, 362, 365, 366, 367
- AIM, 27
- air, ix, 19, 59, 94, 102, 103, 115, 164, 174, 175, 176, 178, 184, 185, 186, 187, 189, 190, 191, 192, 193, 194, 195, 196, 217, 239, 300, 352
- airborne particles, 194
- air-dried, 217
- airways, 281, 286, 359
- alcohol, 6, 11, 20, 30, 36, 51, 68, 184, 201, 263
- alcohol abuse, 184
- alcohol consumption, 11
- alcohol problems, 20
- alcohol use, 30, 263
- alcoholism, 20
- alexithymia, 5
- algorithm, x, 137, 141, 180, 267, 275, 309, 336, 339, 344, 345
- allergic bronchopulmonary aspergillosis, 364
- allergy, 93
- allogeneic, 85
- alpha, 25
- alternative, xi, 18, 23, 74, 101, 115, 130, 145, 157, 319, 333, 344, 405
- alternative medicine, 145
- alternatives, 14, 16, 95, 395
- alters, 60
- aluminium, 108, 350
- alveolus, 206, 207, 223, 225, 226, 227, 262
- Alzheimer's disease, 282, 291
- amalgam, viii, 91, 92, 93, 94, 95, 96, 110, 111, 116, 189, 192, 252, 253
- ambulance, 159
- amine, 107
- ammonium salts, 189
- amorphous, 56
- amphibia, 363
- amputees, 128
- Amsterdam, 411
- anaerobe, 374
- anaerobes, 374, 382, 383
- anaerobic, 358, 372, 374, 382
- anaerobic bacteria, 372, 374
- anaesthesia, 148, 342
- analgesia, 50
- analgesic, 50
- analgesics, 46, 50, 51
- analysis of variance, 133
- analysts, 389
- analytical techniques, 131
- anatomy, 36, 118, 128, 202, 296, 303, 315, 334, 401, 405, 407
- anemia, 46, 172
- anesthesiologists, 181
- anesthetics, 50, 221, 239, 242, 251, 252
- anger, vii, 1, 4, 5
- angiogenesis, 70
- angiotensin, 375
- animal models, 120
- animals, 177, 268, 358
- ankylosis, 65, 328
- ANN, 271, 276, 277
- anorexia, 174
- antagonist, 283
- antagonistic, 58
- antecedents, 4
- antibacterial, 55, 112
- antibacterial agents, 112
- antibiotic, 70, 144, 157, 176, 352, 359, 377, 381
- antibiotic resistance, 176, 381
- antibiotics, xii, 41, 63, 69, 73, 74, 162, 347, 350, 354
- antibody, 167, 168
- anticoagulant, 58
- anticoagulation, 85
- antifibrotic, 70
- antigen, 167, 364
- anti-HIV, 170, 171, 173
- antimicrobial therapy, 355
- antiretroviral, 182
- antisocial behavior, 9
- antitumor, 78
- antiviral, 59

- anxiety, vii, 1, 2, 3, 4, 9, 10, 20, 21, 23, 24, 25, 27, 29, 31, 33, 34, 61, 64, 65, 388, 390, 391, 393, 394, 398, 399
 anxiety disorder, 3
 apnea, 128
 apoptosis, 47
 appendix, 269, 273
 appetite, 7, 60
 application, xi, xii, 12, 25, 45, 58, 65, 71, 73, 75, 80, 95, 98, 99, 101, 105, 108, 114, 132, 139, 178, 214, 216, 217, 220, 236, 239, 246, 295, 318, 320, 326, 327, 329, 334, 341, 347, 355
 applied research, 133
 appraisals, 21, 397
 Argentina, 159
 argument, 140
 Army, 118
 arousal, 4, 5
 arrest, 104
 arson, 384
 ART, 105, 106, 115, 171, 217
 artery, 28, 170
 arthritis, 4
 arthroscopy, 318
 artificial intelligence, x, 267, 268, 271
 aseptic, 178
 ash, 71, 280
 Asia, 36, 364, 369
 Asian, 200
 aspergillosis, 358, 363, 364, 366, 368
 asphyxia, 288
 aspiration, x, xiii, 46, 61, 62, 63, 65, 86, 87, 154, 187, 193, 200, 212, 216, 248, 252, 281, 282, 287, 288, 290, 291, 292, 371, 372, 373, 374, 375, 376, 380, 381, 382, 383, 384
 aspiration pneumonia, xi, xiii, 61, 281, 287, 288, 291, 371, 372, 373, 374, 375, 376, 380, 381, 382, 383, 384
 aspirin, 50
 assertiveness, 396
 assessment, vii, 2, 6, 21, 23, 35, 39, 40, 42, 43, 45, 50, 65, 73, 74, 77, 81, 86, 92, 104, 110, 130, 133, 138, 139, 144, 174, 196, 289, 294, 317, 320, 321, 322, 323, 326, 327, 328, 331, 345, 361, 389, 390
 assessment tools, 50
 assumptions, 15, 30, 136, 222
 asthenia, 174
 asthma, 56
 ASTM, 153
 asymmetry, 286, 387
 asymptomatic, 42, 78, 178, 360, 364, 365, 402, 404
 Athens, 161
 atherosclerosis, 372
 athletes, 153, 154, 159, 160
 atmosphere, 61
 atresia, 256, 258
 atrophy, 59, 72, 318, 331, 334, 361
 attachment, 26, 89, 349, 350
 attitudes, 9, 10, 12, 23, 30, 141, 194, 263, 398
 Australia, 159, 162, 169, 182, 362, 369
 Austria, 295, 303, 344
 autonomy, 387, 390, 395, 396
 autopsy, 84, 369
 autosomal recessive, 361
 availability, 18, 19, 21, 22, 70, 118, 165, 172, 179, 188
 avascular necrosis, 66
 averaging, 108
 avoidance, 6, 10, 11, 287, 292
 avoidant, 17
 awareness, ix, 6, 10, 21, 40, 169, 179, 183, 185, 193, 293

B

- babies, 261
 bacilli, 374, 380
 back pain, 146
 bacteremia, 48, 49, 375
 bacteria, xiii, 51, 57, 60, 66, 71, 92, 100, 118, 164, 175, 176, 184, 186, 291, 348, 350, 371, 372, 373, 374, 375, 377, 378, 379, 380, 382, 384
 bacterial, xii, xiii, 75, 105, 175, 176, 188, 190, 191, 192, 195, 292, 347, 348, 349, 350, 358, 361, 371, 374, 377, 378, 382, 383, 384
 bacterial contamination, 195, 348
 bacterial infection, xii, 347, 348, 350
 baking, 56
 BAL, 362
 barium, 62, 107, 108
 barrier, 48, 158, 165, 167, 353
 barriers, 12, 15, 17, 20, 158, 165, 175
 basketball, 149, 161
 Bayesian, 130, 131, 133, 144
 Bayesian analysis, 131
 Bayesian methods, 133
 beam radiation, 52
 behavior, vii, ix, x, 1, 2, 3, 4, 6, 7, 9, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34, 133, 184, 185, 192, 194, 214,

- 249, 250, 267, 268, 269, 389, 391, 392, 393, 395, 397, 398, 399
- behavior therapy, 24
- behavioral intentions, 14
- behaviours, 2, 9, 10, 11, 17, 18, 19, 23, 26, 27, 29
- Belgium, 181, 303, 311, 312, 337
- beliefs, 6, 12, 13, 15, 16, 29, 141, 388
- benchmark, 119
- benchmarks, 139
- beneficial effect, 56, 209, 375
- benefits, 12, 15, 17, 23, 51, 61, 95, 119, 122, 125, 127, 140, 143, 334, 394
- benign, 8, 365
- benzoyl peroxide, 107
- beverages, 71
- bias, 9, 20, 33, 136, 137, 138, 139, 145, 276
- bicarbonate, 51, 54
- bicycle accident, 149
- binding, 93, 351
- biochemistry, 172
- biocompatible, 100, 156
- biofilms, 193, 374, 375, 381, 383
- biomechanics, 86, 296
- biopsies, 318
- biopsy, 178, 362, 364, 368
- biopsychosocial model, 387
- birds, 362, 366
- birth, 94, 123, 124, 209, 263, 264, 265, 359, 372
- BIS, 107
- bisphenol, 97
- bisphosphonate treatment, 76
- blame, 388
- blaming, 13
- blastomycosis, 367, 368
- bleeding, xii, 6, 28, 36, 48, 49, 50, 347, 348, 359
- blocks, 52, 65, 80
- blood, 27, 52, 63, 67, 70, 84, 157, 164, 165, 166, 167, 169, 170, 171, 175, 177, 178, 179, 181, 182, 222, 362
- blood clot, 157
- blood cultures, 84
- blood flow, 52
- blood supply, 67, 222
- blood vessels, 70
- bloodstream, 57, 359, 361
- body fluid, 51, 164, 179
- body image, 9
- body weight, 51, 168
- bolus, 52, 286, 287, 288, 290, 294
- bonding, viii, 91, 92, 97, 98, 99, 100, 102, 107, 112, 113, 114, 156
- bonds, 99
- bone cancer, 36
- bone density, xi, 301, 317, 326, 328, 330, 333, 335, 336
- bone graft, xii, 69, 235, 256, 259, 260, 262, 264, 317, 321, 335, 347, 351, 355
- bone loss, 41, 317, 349, 350, 351
- bone marrow, 59, 78, 80, 84, 85, 363
- bone marrow transplant, 59, 78, 80, 84, 85
- bone mineral density, 324
- bone morphogenetic proteins, 200
- bone volume, xi, 333, 335, 336, 342
- Boolean logic, 129
- borosilicate glass, 107
- Boston, 87
- bovine, 177, 182, 351, 355
- bovine spongiform encephalopathy, 177, 182
- bowel, 5
- boys, 264
- brain, 36, 153, 271, 320, 363, 372, 377, 381
- brain abscess, 372
- brain tumor, 320
- branching, 112
- Brazil, 159, 160, 199
- Brazilian, 181
- breakdown, 49, 66, 178, 287
- breast cancer, 82, 390, 396
- breastfeeding, 209, 210
- breathing, 57, 154, 287
- British Columbia, 30
- Brussels, 195
- buccal mucosa, 39, 43, 44, 46, 47, 359
- buccal sulcus, x, 199, 239
- buffer, 71
- buildings, 361
- burning, 51, 54, 154
- burnout, 4
- burns, 363
- buttons, 189, 192

C

C++, 341

CAD, 311, 312, 327, 330

cadaver, 321, 324

calcification, 232, 263

calcium, 56, 97, 105, 156, 162, 246, 350, 351

calculus, 40, 41, 42

- calibration, 309, 335, 342
CAM, 311, 312, 327, 330
campaigns, 159
Canada, 30, 123, 128, 166, 337
canals, 402, 404, 405
cancer, vii, 5, 16, 20, 25, 35, 36, 37, 38, 39, 41, 42, 44, 45, 46, 48, 49, 51, 55, 57, 59, 61, 62, 63, 64, 68, 72, 73, 75, 76, 77, 78, 79, 80, 81, 82, 84, 85, 86, 87, 88, 89, 359, 368, 390, 396, 397
cancer treatment, vii, 25, 35, 36, 38, 39, 41, 42, 44, 45, 46, 49, 51, 62, 63, 68, 75, 86
candida, 58
Candida, xii, xiii, 54, 57, 58, 84, 85, 164, 357, 358, 359, 361, 366, 367, 368, 369, 371, 377, 378
candidates, 109, 393
candidiasis, xii, 45, 49, 51, 58, 84, 85, 357, 359, 360, 361, 365, 367, 368
capsule, 361, 366, 370
car accidents, 152
carbohydrate, 358
carbohydrates, 118
carbon, 352
carbon dioxide, 352
carcinoma, 36, 37, 40, 75, 76, 77, 78, 80, 81, 82, 83, 84, 88, 89, 365, 367
carcinomas, 82, 87
cardiologist, 5
cardiovascular disease, 4, 30, 32, 56, 372
cardiovascular system, 201
caregiver, 165, 166, 171, 172, 173
caregivers, 163, 165, 167, 168, 169, 171, 174, 175, 176, 179, 180, 376
caries, viii, x, 7, 37, 39, 41, 42, 43, 44, 45, 49, 50, 51, 54, 59, 63, 64, 71, 72, 73, 89, 91, 92, 94, 96, 100, 101, 102, 103, 104, 105, 109, 110, 112, 113, 114, 115, 118, 149, 151, 161, 199, 209, 211, 213, 233, 234, 235, 236, 252, 260, 262, 263, 372, 381
cartilage, 65
case study, 268, 275
casein, 56
cast, xiii, 289, 296, 309, 310, 312, 313, 318, 320, 407, 408
CAT, 67, 110
catalyst, 107
Caucasians, 151
cavities, vii, viii, 110, 116, 117, 200, 211, 212, 233, 404
cell, 46, 47, 50, 55, 57, 66, 68, 76, 78, 81, 85, 87, 157, 174, 200, 201, 233, 291, 351, 361, 369, 377
cell adhesion, 201
cell culture, 157
cell death, 47, 66, 68, 201
cell differentiation, 200
cement, 74, 102, 105, 106, 114, 115, 156, 214, 219, 220, 246
cementum, 71, 73, 98, 149, 150, 157
Centers for Disease Control (CDC), 110, 167, 176, 180, 181, 184, 186, 190, 193
ceramic, 319
cerebral ischemia, 292
cerebral palsy, 282, 292
check-ups, 7
cheilitis, 58, 360
chemical composition, viii, 91
chemical properties, viii, 91
chemoprevention, 397
chemotherapeutic agent, 44, 45, 75
chemotherapy, 36, 38, 44, 46, 48, 49, 50, 51, 52, 54, 57, 58, 59, 60, 61, 62, 72, 76, 78, 79, 80, 84, 86, 87, 390
chewing, 39, 40, 52, 55, 56, 61, 65, 71, 94, 157, 282, 286, 287, 288, 289, 290, 292, 294
childhood, 9, 80, 149, 209, 214, 221, 235, 263
children, viii, ix, x, 28, 45, 49, 56, 58, 59, 65, 74, 80, 92, 94, 95, 96, 102, 103, 105, 109, 110, 111, 113, 114, 116, 147, 148, 149, 151, 152, 158, 159, 160, 161, 199, 209, 211, 212, 213, 221, 222, 223, 225, 230, 233, 234, 235, 249, 260, 261, 262, 263, 264, 265, 266, 287, 291, 292, 293, 294, 366
China, 36, 76, 333
chloroform, 192
cholinergic, 55
chromosomal alterations, 201
chronic disease, 397
chronic kidney disease, 16
chronic obstructive pulmonary disease, 56, 282, 292, 373
chronic pain, 4
chronic renal failure, 368
chronic stress, 5
CHS, 117
cigarette smoking, 349
cigarettes, 20
cis, 279
cisplatin, 36, 76, 79
citizens, 140, 181
classes, 72, 172, 269, 271, 272, 275, 277, 278
classification, 37, 48, 85, 87, 108, 116, 149, 151, 152, 161, 201, 291, 326, 354

-
- cleaning, xiii, 7, 8, 10, 44, 45, 49, 51, 56, 58, 65, 73, 102, 189, 214, 371, 376, 377, 380
 cleft lip, x, 199, 200, 201, 202, 203, 204, 205, 206, 207, 209, 211, 212, 214, 221, 222, 223, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 237, 238, 239, 249, 252, 256, 257, 260, 261, 262, 263, 264, 265, 266
 cleft palate, x, 200, 201, 208, 209, 223, 248, 252, 256, 261, 264
 clinical approach, 114, 148, 158
 clinical assessment, 74
 clinical examination, xii, 92, 104, 155, 213, 225, 243, 357, 361, 402
 clinical judgment, 120, 121, 122, 128
 clinical oncology, 82
 clinical presentation, xii, 357
 clinical trial, 27, 70, 80, 83, 86, 102, 114, 115, 120, 131, 136, 142, 145, 355
 clinical trials, 27, 70, 83, 102, 120, 136, 142, 145
 clinically significant, 358
 clinician, 100, 107, 141, 361, 402, 403, 405, 408, 410
 clinics, ix, 113, 152, 176, 184, 185, 187, 189, 195, 243
 closure, 41, 153
 clustering, 187
 clusters, 167
 CMV, 85, 164, 173
 CNS, 361, 362
 Co, 110, 111, 112, 261
 CO₂, 352, 356
 coaches, 159
 Cochrane reviews, 123
 coding, 389, 392
 coffee, 51
 cognitive behavior therapy, 24
 cognitive domains, 124
 cognitive load, 21
 cognitive process, 4, 14, 21
 cognitive processing, 21
 coherence, 17, 24, 27, 32
 cohort, 7, 113, 171, 327, 375
 coliforms, 186, 190
 collaboration, x, 200, 361, 399
 collagen, 66, 70, 98, 351, 355
 college students, 16, 24
 colonization, 58, 84, 193, 282, 350, 361, 364, 373, 375, 376, 382, 383
 colorectal cancer, 16, 25
Columbia, 362, 366
 commensals, 358, 359, 372, 374
 commodity, 118, 140
 communication, xiii, 27, 46, 201, 211, 212, 380, 387, 388, 389, 390, 391, 392, 394, 395, 396, 397, 398, 399
 communication skills, 392, 395, 399
 communities, 100
 community, 2, 22, 287, 373, 382
 comorbidity, 25
 compassion, 6
 competence, vii, 1, 7, 9, 26, 33, 166, 180, 388, 398
 competency, 38
 compilation, 185
 complement, viii, 117, 242
 complementarity, 9, 389, 397
 complex interactions, 233
 complexity, 68, 137, 148, 158, 200
 compliance, 9, 11, 12, 24, 40, 42, 43, 45, 56, 65, 71, 73, 77, 92, 109, 110, 140, 173, 196, 197, 249, 250, 252, 389, 393
 complications, vii, xi, xii, xiii, 35, 36, 38, 39, 43, 44, 46, 49, 54, 55, 57, 62, 63, 73, 75, 76, 77, 78, 80, 81, 82, 84, 86, 87, 88, 110, 155, 158, 162, 235, 291, 317, 333, 347, 349, 350, 353, 362, 401, 402
 components, xiii, 2, 4, 5, 9, 10, 13, 17, 99, 107, 138, 140, 222, 233, 303, 304, 387, 388, 391
 composites, viii, 92, 97, 101, 106, 107, 108, 109, 110, 116
 composition, viii, 60, 71, 91, 100, 107, 115, 235, 263, 349
 compounds, 54, 171, 189, 192
 computation, 271
 computed tomography, xi, 295, 320, 321, 322, 323, 324, 325, 327, 328, 404, 405
 computer graphics, 337
 computer science, x, 267, 268
 computer software, 268
 computing, 338
 concentration, 8, 44, 45, 56, 103, 176, 372, 375, 376
 conceptual model, vii, 1, 389
 conceptualization, 122
 conceptualizations, 119
 concordance, 388
 concussion, 153, 155, 157
 conditioning, 98, 352, 356
 condom, 16, 33
 conduction, 171
 conductivity, 106
 confidence, vii, 1, 4, 15, 18, 26, 180, 296, 388
 configuration, 107, 115, 116

- conflict, 388, 394
conformity, 186
congenital malformations, x, 199
Congress, 328, 329, 405
Connecticut, 393
connectionist, 271
connective tissue, 47, 65, 200
conscientiousness, 3
consciousness, vii, 1, 2, 9, 26, 27, 30, 382
consensus, viii, 11, 117, 120, 122, 126, 127, 129, 130, 132, 134, 136, 137, 138, 140, 323, 360
consent, 171, 214
conservation, 288
CONSORT, 141, 145
conspiracy, 125, 140, 143
constraints, 136, 158
construct validity, 34
construction, 41, 96, 138, 327, 345
consulting, 395
consumption, 11, 25, 33, 68, 195, 294
contact time, 45
contaminants, 352
contamination, ix, 102, 103, 109, 110, 165, 166, 169, 172, 175, 182, 184, 185, 186, 191, 192, 193, 194, 195, 196, 197, 213, 348
continuity, 38, 256
contractions, 286
control, vii, ix, xii, 1, 2, 5, 6, 8, 11, 16, 20, 23, 24, 25, 26, 30, 36, 38, 40, 41, 45, 50, 51, 63, 73, 76, 94, 95, 101, 104, 106, 107, 109, 110, 120, 125, 145, 147, 174, 180, 182, 184, 188, 194, 195, 196, 197, 233, 234, 235, 249, 262, 271, 288, 293, 308, 309, 315, 316, 319, 347, 348, 350, 351, 352, 354, 368, 372, 373, 375, 376, 378, 380, 382, 388, 389, 394, 395, 396, 397, 399
control group, 233, 235, 376, 380, 395
controlled studies, 65, 352
controlled trials, 85, 134
conversion, 115, 186
cooling, 52, 80
COPD, 282
Copenhagen, 114, 161
coping, 6, 11, 17, 34
coping strategies, 6, 7, 21
copolymer, 154
copper, 93, 94
cornea, 177
coronary artery disease, 28
coronary heart disease, 3, 5, 16, 25, 28
correlation, 11, 86, 94, 285, 287, 317, 329, 374, 382
correlations, 20, 34, 317
corrosion, 93
cortex, 317
cost-benefit analysis, 12
cost-effective, viii, 92, 93, 96, 103, 127, 130, 145
costs, xii, 12, 14, 15, 130, 137, 139, 140, 141, 158, 159, 307, 318, 319, 357, 395
cotton, 39, 40, 44, 50, 103, 214, 217, 243, 352, 358, 377
cough, 61, 173, 174, 376, 384
coughing, 282
counseling, vii, 35, 38, 43, 44, 45, 60, 209, 213, 393, 394
countermeasures, xiii, 371
coupling, 107
covering, 154, 158
CPG, 51
CPR, 297, 298, 299, 301, 302
crack, 150
cranial nerve, 36, 37
craniofacial, 65, 128, 200, 325, 390
craniomaxillofacial, 318, 332
cranium, 200
CRC, 133, 144
creativity, 6
credibility, 162
creep, 93
critical points, ix, 184
critical thinking, 144
critically ill, 282
criticism, vii, 1, 9, 26
cross-sectional, 298, 301, 302, 335, 336, 405
crown, viii, xiii, 39, 41, 43, 71, 72, 91, 95, 96, 111, 117, 128, 150, 152, 155, 156, 157, 160, 224, 300, 318, 407, 411
CRT, 54
cryotherapy, 52, 80
cryptococcosis, 361, 362, 365, 367, 369
Cryptococcus, xii, 357, 358, 361, 362, 366, 367, 368, 369, 370
CSF, 362
CT scan, 319, 329, 330, 341, 342
cues, 17, 22, 391
culture, 17, 157, 187, 358, 363
culture media, 157
curettage, 41, 248, 351
curing, 107, 108, 114, 313, 314
current limit, 127
curriculum, 144, 393
cycles, 130, 272, 279, 289, 290, 390

cycling, 152
 cyst, 40, 43, 212, 213
 cystic fibrosis, 176, 182
 cysts, 212
 cytokine, 47, 291
 cytokines, 47, 57, 282
 cytopathology, 369
 cytoprotective, 54
 cytotoxic, 36, 52
 cytotoxicity, 38

D

daily living, 53
 danger, 14, 19, 20, 157
 data analysis, 126, 131, 133, 134, 135
 data mining, 130
 data set, 317, 337
 data structure, 271
 database, 93
de novo, 136
 death, xiii, 36, 46, 47, 61, 66, 68, 201, 362, 371, 372, 376
 death rate, 362
 deaths, 149
 debridement, 69, 70, 350, 351, 352, 354
 decay, viii, 44, 71, 110, 118, 119
 deciduous, viii, 91, 105, 111, 116, 221, 222, 223, 225, 226, 227, 229, 230, 231, 232, 233, 234, 235, 236, 243, 251, 252, 253, 254, 255, 256, 261, 262, 263, 264
 decision makers, 139
 decision making, xiii, 21, 22, 26, 121, 122, 125, 126, 134, 143, 144, 387, 388, 393, 394, 396, 397
 decision trees, 132, 141
 decision-making process, 23, 126, 130, 136, 140
 decisions, 20, 32, 125, 132, 137, 139, 140, 141, 145, 388, 389, 394, 395, 397, 399
 decontamination, 185, 352, 356, 384, 385
 defects, vii, xi, 38, 94, 95, 96, 97, 157, 201, 230, 232, 233, 263, 265, 333, 334, 335, 336, 341, 344, 345, 351, 355, 356
 defense, 28, 71, 166, 373, 374, 375
 defense mechanisms, 71, 374, 375
 defibrillator, 31
 deficiency, 236, 256, 287, 358
 deficit, 40
 deficits, 361
 definition, 121, 127, 268, 269
 deformation, 316

degenerate, 359
 deglutition, 61, 283, 284, 286, 287, 288, 294
 degradation, 99, 100, 112
 dehydration, 38, 61, 74, 105
 delivery, xii, 52, 131, 167, 347, 355, 359, 372, 376
 demineralized, 189
 denial, 21, 30
 Denmark, 112, 159, 176
 density, xi, 70, 112, 301, 317, 324, 326, 328, 329, 330, 333, 335, 336
 density values, 330
 dental caries, 42, 44, 54, 59, 63, 73, 105, 110, 118, 151, 161, 209, 213, 233, 234, 235, 260, 372, 381
 dental clinics, ix, 152, 184, 185, 187, 195, 243
 dental implants, 43, 88, 128, 320, 321, 326, 327, 328, 331, 351, 353
 dental injuries, ix, 147, 148, 149, 150, 151, 152, 153, 158, 159, 160, 161, 162
 dental plaque, 29, 42, 44, 45, 50, 62, 72, 234, 235, 282, 354, 372, 373, 374, 375, 377, 382, 383, 385
 dental profession, x, 38, 40, 42, 68, 132, 200, 209, 213, 223, 234, 236, 237, 243, 249
 dental treatments, 39, 45, 63, 288
 dentin, viii, 91, 92, 97, 98, 99, 100, 105, 109, 112, 113, 114, 116, 150, 156, 233
 dentist, viii, x, 4, 5, 6, 7, 8, 9, 10, 11, 49, 73, 97, 101, 117, 119, 120, 121, 122, 123, 126, 128, 139, 140, 141, 154, 158, 159, 186, 196, 197, 199, 255, 267, 268, 329, 342, 390, 391, 392, 394, 395, 396, 398, 399, 404
 dentistry, vii, viii, 91, 92, 93, 94, 97, 99, 100, 105, 109, 110, 111, 113, 114, 115, 117, 118, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 131, 132, 134, 137, 139, 143, 144, 145, 158, 176, 181, 182, 188, 194, 195, 196, 320, 323, 324, 326, 327, 353, 390, 391, 393, 394, 395, 396, 398, 399
 dentists, viii, x, 101, 118, 119, 121, 124, 125, 126, 137, 139, 158, 159, 181, 185, 187, 188, 192, 193, 194, 195, 197, 249, 267, 268, 380, 390, 391, 392, 395, 398, 399
 denture, 41, 43, 49, 51, 54, 56, 57, 58, 73, 74, 307, 341, 366, 368, 374, 382, 391, 395
 dentures, viii, xiii, 39, 41, 44, 51, 54, 58, 74, 117, 128, 288, 327, 358, 359, 360, 361, 362, 371, 374, 391
 Department of Health and Human Services, 80
 dependent variable, 7, 14
 deposition, 174
 deposits, 164
 depressed, 7, 30, 61, 286, 360, 362, 363, 364, 382

- depression, 4, 7, 23, 25, 28, 29, 33, 53, 61, 64, 65, 193
depressive disorder, 34
depressive symptoms, 5, 7, 9, 31, 32
deprivation, 149, 160
dermatitis, 63
destruction, 43, 47, 71, 72, 89
detection, 44, 58, 73, 305, 369
detergents, 57
detoxification, 352
developed countries, 174, 372
developmental delay, 290
deviation, xii, 133, 275, 334, 340, 342, 344
diabetes, 4, 28, 31, 33, 70, 350, 354, 361, 363, 373
diabetes mellitus, 373
diabetic patients, 33, 350, 390, 397
diaphoresis, 56
dichotomy, 4, 131
diet, 2, 44, 45, 48, 51, 53, 54, 56, 61, 62, 71, 82, 92, 118, 211, 213, 358
dietary, x, 48, 53, 60, 62, 71, 199, 211, 235, 375
dietary habits, 62, 235
diets, 376
differential diagnosis, 243, 359, 361
differentiation, 233, 351, 354
diffusion, 168
digestive tract, 288, 358, 372
dimethacrylate, 107
diodes, 303
diphenhydramine, 50
directionality, 136
disability, 3, 282
disabled, 288
discomfort, x, 10, 38, 46, 54, 64, 73, 81, 199, 239, 251, 254, 306, 393
discordance, 137
disease progression, 5
diseases, vii, xii, 35, 40, 41, 70, 73, 80, 128, 139, 161, 184, 185, 192, 268, 276, 282, 292, 348, 357, 358, 361, 364, 372
disinfectant, 189
disinfection, 59, 99, 176, 177, 178, 184, 185, 187, 189, 193, 194, 360, 361
dislocation, 150, 153
disorder, 3, 24, 40, 65, 200, 202, 223, 256, 282, 391
dispersion, 193, 362
displacement, 150, 152, 156, 223, 248, 256, 287, 312
dissatisfaction, 388
disseminate, 57, 75, 125
distilled water, 187
distortions, 320
distraction, 318
distress, 17, 21, 27, 38, 389
distribution, 107, 110, 176, 187, 223, 283, 285, 293, 307
diuretics, 51
divergence, 390
diversity, 202
diving, 149, 152
division, 201, 286, 293
DNA, 167, 170
docetaxel, 36, 76
doctor-patient, 389, 390, 395
doctors, 187, 380, 387, 388, 390, 391, 395
dogs, 354, 355
dominance, 389, 391
doors, 186
dosage, 46, 170, 171
double-blind trial, 79
Down syndrome, 282, 286, 288, 290, 293, 294, 369
drainage, 39
drinking, 16, 24, 30, 36, 39, 51, 61, 184, 291
drinking water, 184
drug addict, 166
drug delivery, 355
drug dependence, 66
drug exposure, 52
drug resistance, 358
drug therapy, 36, 184
drug treatment, 358
drug-resistant, 172
drugs, 6, 36, 52, 55, 70, 85, 120, 170, 171, 172, 173, 361
drying, 112, 216, 239, 362
drying time, 112
duodenal ulcer, 5
dura mater, 177
durability, viii, 23, 91, 93, 95, 99, 102, 111, 252
duration, 46, 52, 55, 87, 101, 108, 171, 172, 179, 364
dust, 93, 164, 173, 174
dyes, 112
dyskinesia, 294
dysmetabolic, 358
dysphagia, 38, 46, 61, 62, 63, 281, 282, 287, 288, 291, 292, 294, 359, 374, 375, 381
dysphoria, 388
dysplasia, 97

E

- earth, 152, 159
 East Asia, 364
 eating, 32, 39, 44, 52, 56, 60, 61, 62, 66, 82, 287, 291
 eating disorders, 32
 ecology, 381
 economic status, 149, 151
 economics, 70, 134, 140
 edema, 360
 education, 31, 33
 educational programs, 192, 194
 elasticity, 93
 elderly, viii, xi, xiii, 33, 118, 281, 287, 291, 292, 294, 359, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384
 elderly population, 383
 elders, 382
 electrodes, 177
 electrolyte, 38
 electrolyte imbalance, 38
 electrolytes, 57, 71
 electromagnetic, 331
 electromyography, 294
 elementary school, 160
 elk, 177
 email, 91, 148
 embryonic development, 200
 EMG, 293, 294
 emission, 193
 emotion, 2, 6, 21, 32
 emotional, vii, 1, 4, 5, 6, 8, 10, 17, 18, 21, 22, 24, 26, 27, 30, 32, 34, 124, 209, 387, 389
 emotional distress, 17, 21, 389
 emotional experience, 8, 34
 emotional intelligence, vii, 1, 6, 26, 27, 30
 emotional reactions, 21, 32
 emotionality, 26
 emotions, 2, 5, 6, 21, 22
 empathy, 390
 empowered, 120, 140
 empowerment, 395, 399
 enamel adhesives, viii, 92, 97, 113
 encapsulation, 93
 encephalopathy, 177, 182
 encouragement, 13, 73
 endocarditis, 372
 endocrine, 5, 361
 endocrine disorders, 361
 endothelial cells, 66
 endothelium, 47
 endotoxins, 59, 352
 endotracheal intubation, 161
 end-stage kidney disease, 166
 energy, 8, 154
 engagement, 8
 England, 105, 116, 149, 160, 381, 390
 environment, ix, xi, 4, 7, 41, 56, 74, 94, 100, 148, 160, 163, 165, 166, 167, 168, 174, 179, 180, 181, 183, 184, 193, 194, 195, 196, 200, 213, 214, 263, 268, 333, 335, 364, 374
 environmental change, ix, 147, 148
 environmental conditions, 160
 environmental contamination, 194
 environmental factors, 13, 17, 201, 233
 Environmental Protection Agency, 184
 enzyme inhibitors, 375
 enzymes, 112, 282, 359, 375
 epidemic, 33, 180, 194
 epidemics, 361
 epidemiologic studies, 282
 epidemiology, 79, 110, 145, 181, 291
 epigenetic, 120
 epilepsy, 148, 149
 epistaxis, 40
 epithelial cell, 291
 epithelium, 57, 59, 200, 233, 375
 Epstein-Barr virus, 36, 76, 173
 equilibrium, 102
 equity, 140
 erbium, 350
 erosion, 51
 error management, 332
 erythematous, 46, 54, 58, 359, 360
Escherichia coli, 59, 184, 186
 esophagitis, 358
 esophagus, 281, 286, 359
 esthetics, x, 65, 73, 128, 200, 233, 296, 348
 etching, 97, 98, 99, 102, 103, 114
 ethanol, 98, 189
 ethics, 128
 ethnic minority, 92
 ethylene, 107
 ethylene glycol, 107
 etiologic factor, 223, 225, 373
 etiology, 3, 89, 118, 201, 222, 223, 230, 233, 364, 372, 373, 380, 381
 Europe, 197
 European Commission, 195

European Community, 195
European Union (EU), 29, 197
Evidence-Based Dental Practice, 125, 143
evil, 372
evolution, viii, 91, 92, 118, 120, 134, 177, 180, 363
examinations, 49, 73
exclusion, 129, 137, 138, 141
execution, 125
exercise, 18, 25, 65, 210
exfoliation, 95
exocrine, 55
expectancy-value theory, 13
experimental condition, 395
expertise, viii, 117, 119, 120, 121, 122, 123, 133, 139, 140, 141, 159, 388
exposure, ix, 52, 71, 74, 94, 103, 133, 150, 152, 156, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 179, 180, 181, 182, 184, 233, 318, 321, 328, 350, 354, 361, 364, 394
Exposure, 103, 163
external environment, 200, 364
external magnetic fields, 319
external validity, 127
extraction, viii, x, xiii, 39, 41, 42, 43, 45, 62, 63, 67, 68, 70, 74, 88, 117, 137, 155, 156, 169, 176, 200, 216, 223, 224, 225, 236, 242, 246, 247, 248, 253, 254, 255, 261, 275, 353, 364, 391, 393, 395, 401, 402, 403, 404, 405
extraction process, 402
extrusion, 150, 155, 157
eye contact, 391
eyes, 36, 179, 334, 342, 391

F

fabricate, 307
fabrication, 313, 314, 323
facial pain, 398
factorial, ix, 147, 148
failure, 5, 8, 9, 11, 20, 25, 32, 93, 96, 100, 194, 233, 296, 348, 353, 373, 404
family, 7, 105, 164, 233, 249, 288, 290
family environment, 7
family history, 233
fatigue, 5, 7, 283
fax, 91, 148
FDI, 149, 154, 160
fear, 11, 20, 21, 29, 31, 125, 213, 236, 249, 288, 290, 391
fear response, 391

fears, 122
feces, 362, 363
feedback, 13, 18, 159, 292, 393
feeding, 51, 62, 63, 210, 211, 213, 235, 261, 286, 291, 373, 375, 376
feelings, 4, 5, 6, 7, 9, 12, 19, 20, 21, 22, 29
fees, 158
females, 151, 201, 227
fermentable carbohydrates, 118
fetal, 200, 376
fever, 54, 57, 174, 365, 376, 380
fibers, 285, 351
fibroblast, 70
fibroblast proliferation, 70
fibrogenesis, 62
fibrosis, x, 38, 61, 62, 63, 65, 74, 176, 182, 199, 239
filler particles, 107, 108
fillers, 107, 108, 186, 190
film, 296, 328
films, 189, 193, 194
filters, 175, 176, 187
filtration, 192
Finland, 3, 111
first generation, 97
fish, 76, 94
fistulas, 73, 74
fixation, 157, 301, 307, 313, 329
flavors, 60
flexibility, 139
flora, xiii, 49, 71, 84, 85, 175, 282, 371, 374, 375
flow, 39, 43, 52, 53, 54, 56, 57, 60, 81, 88, 92, 103, 108, 144, 176, 187, 210, 373
flow rate, 43, 52, 53, 56, 60, 88
fluid, 28, 51, 62, 107, 169, 181, 184, 374
fluid balance, 51
fluoride, 44, 45, 50, 56, 63, 71, 73, 74, 75, 77, 88, 101, 102, 103, 104, 105, 108, 110, 113, 114, 115, 214, 217, 218
fluorides, 56, 71
flushing, 56
focusing, 69, 171, 176, 372, 396
folic acid, 201, 261
food, 42, 45, 50, 51, 54, 56, 60, 61, 71, 281, 283, 287, 289, 292, 294, 375, 376
Food and Drug Administration, 154
food intake, 60
football, 149, 152, 153
foramen, 208, 297
forceps, 247, 248
foreign language, 130

fractionation, 46, 53, 86, 88
 fracture, 66, 67, 69, 71, 72, 93, 95, 102, 150, 152, 153, 154, 156, 157, 353, 402
 fractures, 78, 149, 151, 156, 160, 407
 France, 117, 281, 288, 293
 free radical, 107
 free radicals, 47
 fructose, 118
 fruits, 51
 frustration, 3
 fulfillment, 38
 functional analysis, 397
 funding, 23, 140, 142
 fungal, xii, 54, 57, 58, 84, 357, 358, 363, 366, 367
 fungal infection, xii, 54, 57, 58, 357, 366
 fungi, xii, 57, 60, 164, 175, 357, 358, 362, 363, 364, 365, 372
 fungus, 54, 58, 365
 fusion, 329
 fuzzy logic, 271, 280

G

Gamma, 93
 gastric, 5, 44
 gastroenteritis, 363
 gastrointestinal, 5, 46, 79, 291, 365
 gastrointestinal tract, 291
 gauge, 409
 gel, 44, 45, 58, 63, 85, 88, 98
 gels, 71
 gender, 17, 34, 179
 gene, 47, 55, 230, 233
 gene therapy, 55
 general anesthesia, 161, 169, 225, 254, 255
 general intelligence, 10
 generation, viii, 23, 92, 97, 98, 99, 100, 101, 112, 123, 130, 132, 138, 141
 genes, 47, 200, 201, 263
 genetic control, 233
 genetic disorders, 233
 genetic factors, 223
 genetics, 17, 262
 Geneva, 80, 161
 genomic, 120
 geriatric, 292
 Germany, 297, 298, 299, 301, 302, 303, 304, 305, 306, 308, 310, 311, 344, 410
 gingival, 4, 25, 28, 45, 49, 89, 169, 181, 212, 213, 235, 312, 317, 349, 368, 372, 374, 375, 385

gingivitis, 3, 4, 6, 24, 25, 34, 42, 43, 45, 49, 50, 51, 57, 59, 75, 170, 235, 261, 354
 gland, 37, 53, 54, 55, 71, 77, 80, 81, 83, 84, 86, 362
 glass, 74, 92, 101, 102, 104, 105, 106, 107, 108, 110, 113, 114, 115, 156, 214, 219, 220, 305
 glasses, 175, 188, 210
 glaucoma, 56
 gloves, 174, 175, 178, 179, 187, 188
 glucose, 118
 glutaraldehyde, 189, 192
 glycol, 107
 glycoproteins, 375
 glycosylated, 390
 glycosylated hemoglobin, 390
 goals, 18, 23, 125, 139, 270
 gold, 70, 296, 306, 409
 gold standard, 70, 296, 306
 Good Manufacturing Practice, 195
 GPS, 303
 grading, 53, 62, 69, 145
 graduate students, 123
 grafting, xi, 256, 257, 333, 351
 grafts, 334
 Gram-negative, 374, 380
 Gram-positive, 57
 granulocyte, 62
 graphite, 352
 grouping, 133
 groups, 21, 30, 97, 140, 149, 151, 233, 262, 283, 350, 376, 395
 growth, x, 52, 65, 96, 134, 153, 162, 175, 199, 200, 201, 221, 223, 230, 235, 256, 260, 264, 292, 354, 358, 360, 363
 growth factor, 52, 200, 230
 growth factors, 200
 guidance, xi, 293, 295, 296, 303, 309, 312, 314, 317, 318, 319, 326, 331, 333, 335, 342
 guidelines, 50, 79, 93, 111, 115, 120, 121, 122, 126, 128, 130, 132, 136, 138, 139, 141, 143, 144, 167, 171, 172, 180, 181, 193, 323
 guilt, 7
 gums, 359, 364, 365
 gustatory, 39, 60
 gymnastics, 149

H

HAART, 170, 172
 habitat, 164, 363
 half-life, 52

-
- handicapped, 291
handling, 94, 107, 283
hands, 189, 192
HAPA, 12
happiness, vii, 1, 8
hard tissues, ix, xii, 66, 98, 147, 148, 213, 347
harm, 9, 51, 133, 372
harmony, 372
Hawaii, 369
hazards, ix, 184, 185, 194, 195
HBV, 164, 165, 166, 167, 168, 179, 180, 181, 184, 188, 189, 192
HBV infection, 167, 168
head and neck cancer, viii, 35, 36, 38, 52, 60, 62, 63, 75, 76, 77, 78, 79, 81, 82, 83, 84, 85, 86, 87, 326
healing, 5, 39, 41, 47, 48, 49, 51, 58, 66, 68, 70, 73, 74, 88, 157, 159, 162, 249, 350, 351, 354, 402
Health and Human Services, 80
Health Belief Model (HBM), 11, 12
health care, ix, xiii, 21, 38, 77, 78, 80, 105, 123, 131, 137, 138, 139, 140, 163, 164, 165, 167, 168, 169, 170, 171, 172, 173, 174, 175, 177, 178, 179, 180, 181, 193, 371, 372, 375, 376, 377, 378, 380, 384, 387, 388, 393, 396, 397, 398
health care professionals, ix, 163, 164, 167, 168, 169, 171, 172, 173, 177, 178, 179, 393
health care workers, 181, 193
health education, 23, 34
health problems, 4, 9, 21, 144, 181, 185, 293, 294
health psychology, 19, 23
health services, 159
health status, 5, 17, 26, 27, 29, 31, 32, 213, 261, 263, 373
healthcare, 182, 196, 392
health-promoting behaviors, 3
hearing, 40, 211
heart, 3, 5, 16, 19, 20, 25, 27, 28, 31, 32, 377
heart disease, 3, 5, 16, 19, 20, 25, 28
heart failure, 5, 25, 32
heat, 65, 156, 193, 316
heaths, 312
hedonic, 60
height, 152, 256, 316, 319
helping behavior, 16
hematologic, 70
hematological, 46, 172, 363
hematology, 80
hematopoietic, 46, 50, 57, 85
hematopoietic stem cell, 46, 50, 57, 85
hemoglobin, 390
hemophiliacs, 166
hemoptysis, 174
hemorrhage, 50, 63, 248, 317
hemostasis, 216
hepatitis, 164, 165, 166, 167, 168, 169, 179, 181, 182, 188, 189, 192, 195, 197
hepatitis A, 166
hepatitis B, 164, 165, 166, 167, 179, 184, 188, 195, 196
hepatitis C, 164, 165, 166, 169, 181, 182, 184, 197
herpes, 59, 73, 85, 188, 189, 192
herpes simplex, 59, 85
herpes zoster, 73
heterotrophic, 358
heuristic, 19, 21, 22
high resolution, 345
high risk, 20, 21, 22, 36, 52, 63, 68, 96, 212
high school, 30, 151, 161
high temperature, 362
high-level, 376
high-risk, ix, 20, 30, 78, 106, 109, 147, 148, 149, 375
high-risk populations, 375
high-speed, 175, 193
hip, 29, 391
hip fracture, 29
Hiroshima, 371
Hispanics, 388
histological, 365
histology, 263, 265, 361, 363
histoplasmosis, 365, 366, 367, 370
HIV, xii, 164, 165, 166, 169, 170, 171, 172, 173, 181, 182, 184, 188, 189, 197, 357, 358, 362, 365, 367, 369, 370
HIV infection, 165, 170, 171, 172, 173, 365, 370
HIV test, 172
HIV-1, 182
hockey, 149, 153, 161
Holland, 280, 345, 411
homeless, 30
homogenous, 131, 136, 137
homolog, 230
hopelessness, vii, 1, 3, 7, 26
hormone, 145
horse, 152
hospital, 89, 152, 161, 181, 185, 196, 382
hospitalization, 38, 288, 375
hospitalized, 48, 288, 292, 363, 380, 382, 384
hospitals, 152, 312

-
- host, 5, 36, 48, 68, 85, 112, 165, 173, 174, 363, 364, 373, 374, 375
 host tissue, 364
 hostility, 3, 4, 5, 29, 389, 391
 households, 149
 HPM, 17
 HPV, 36
 HSCT, 50, 57
 human, vii, 8, 17, 94, 112, 120, 127, 164, 165, 172, 175, 177, 195, 268, 271, 293, 315, 330, 337, 340, 354, 358, 363, 366, 367, 368, 369, 372, 397
 human brain, 271
 human experience, 8
 human immunodeficiency virus, 164, 366, 367, 368, 369
 Human Kinetics, 292
 human subjects, 120
 humans, 177, 182, 263, 265, 293, 358, 362, 372, 374
 hybrid, 98, 99, 116, 337
 hybridization, 112, 162
 hybrids, 108
 hydrate, 48
 hydration, 55
 hydro, 98
 hydrogen, 51, 352
 hydrogen peroxide, 51, 352
 hydrolysis, 97
 hydrophilic, 98
 hydroxide, 156, 162, 246
 hydroxyapatite, 351, 355
 hygiene, x, xii, xiii, 3, 7, 25, 28, 29, 32, 34, 38, 39, 40, 41, 42, 43, 44, 45, 48, 49, 50, 51, 56, 58, 62, 65, 68, 71, 73, 74, 75, 92, 94, 109, 119, 178, 200, 213, 214, 217, 234, 235, 236, 249, 281, 282, 288, 347, 349, 350, 358, 361, 371, 373, 374, 375, 376, 377, 380, 383, 384
 hygienic, ix, 39, 41, 58, 176, 178, 183, 185, 194, 196, 384
 hyoid, 283, 284, 286
 hyperbaric oxygen therapy, 70, 88
 hypersensitivity, 72, 111
 hypersensitivity reactions, 111
 hypertensive, 390
 hypoparathyroidism, 361
 hypoplasia, 95, 214, 230, 231, 232, 233, 234
 hypotension, 54
 hypothesis, 2, 17, 21, 22, 131, 133, 223, 232, 389, 390
 hypothyroidism, 361
 hypoxia, 66
 hypoxic, 66
-
- I
-
- iatrogenic, 182
 ICD, 161
 ice, 51, 52, 55, 149, 153
 ICU, xi, 281, 286, 292, 385
 id, 378
 identification, 2, 23, 194, 337, 361, 367, 401
 IgG, 361
 illusion, 21
 IMA, 186, 191, 193
 imagery, 22
 images, x, xii, 8, 22, 67, 267, 317, 322, 327, 330, 333, 335, 336, 342, 345
 imaging, xi, 295, 296, 300, 307, 312, 315, 316, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 405
 imaging techniques, 322
 immersion, 97
 immigrants, 33
 immune activation, 25
 immune disorders, 361
 immune response, 5, 68
 immune system, xii, 357, 364, 372
 immunity, xiii, 32, 282, 371
 immunization, 185
 immunocompromised, 38, 80, 85, 174, 175, 184, 194, 363, 401
 immunodeficiency, 164, 165, 176, 366, 367, 368, 369
 immunofluorescence, 176
 immunoglobulin, 57, 180
 immunoglobulins, 168
 immunological, ix, 163, 167, 172, 361
 immunology, 119
 immunosuppression, 36
 immunosuppressive, 79, 362, 363
 immunosuppressive therapies, 362
 impacted teeth, 39
 impairments, 48, 53, 60, 282, 292
 implant failures, 350
 implant planning, xi, 295, 296, 300, 301, 302, 317, 325, 326, 327
 implantology, xi, 145, 320, 321, 322, 326, 327, 328, 329, 333, 334, 337, 344, 349
 implants, viii, xi, xii, 39, 41, 43, 117, 128, 177, 189, 295, 296, 301, 317, 318, 319, 320, 321, 322, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334,

- 335, 336, 341, 342, 344, 345, 347, 348, 349, 350, 351, 353, 354, 355
- implementation, 18, 22, 54, 123, 131, 140, 144, 174, 178, 268, 269, 271, 272, 273, 296
- impulsiveness, 4, 30
- impulsivity, vii, 1, 3, 4, 29
- in situ, 11, 20, 21, 37, 128, 401
- in vitro, 101, 113, 120, 317, 355, 361
- in vivo, 112, 317, 322
- incentive, 18
- incidence, vii, ix, xii, xiii, 5, 35, 36, 38, 46, 49, 51, 58, 59, 62, 63, 67, 71, 73, 75, 77, 79, 80, 88, 110, 147, 148, 151, 153, 160, 165, 181, 182, 292, 349, 357, 359, 371, 373, 374, 376, 377, 378, 379, 382, 385, 390, 404
- incisor, 110, 151, 160, 222, 223, 224, 225, 226, 227, 228, 230, 231, 232, 234, 238, 242, 246, 274, 317
- inclusion, 129, 137, 138, 141, 151, 233, 235
- income, 24
- incubation, 186
- India, 117, 160, 368
- Indian, 82, 366, 367, 405
- Indiana, 145
- indication, 246, 318, 370
- indicators, 5, 25, 33, 189, 194, 294, 349, 352
- indices, 119, 130
- indigenous, 374
- indirect effect, 71
- indirect measure, 394
- individual character, 17
- individual characteristics, 17
- individual differences, 3, 136, 393, 396
- induction, 36, 76, 200
- induction chemotherapy, 36, 76
- infants, x, 110, 199, 209, 211, 212, 213, 217, 221, 260, 261, 263, 264, 372
- infarction, 25
- infection, ix, x, xii, xiii, 36, 42, 48, 49, 50, 54, 57, 59, 66, 69, 76, 84, 85, 92, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 177, 179, 181, 182, 183, 184, 185, 188, 193, 194, 195, 196, 249, 281, 282, 288, 291, 296, 348, 350, 351, 352, 357, 359, 361, 362, 363, 364, 365, 366, 367, 369, 370, 372, 373, 381, 382, 401, 405
- infections, xii, 36, 37, 38, 39, 43, 46, 48, 49, 50, 57, 58, 59, 65, 68, 75, 85, 119, 165, 176, 178, 181, 185, 192, 194, 195, 197, 211, 288, 292, 347, 348, 350, 354, 355, 357, 358, 361, 362, 363, 364, 365, 372, 373, 376, 380, 382, 383, 384, 385
- infectious, viii, ix, xii, 5, 91, 92, 163, 165, 166, 177, 178, 179, 180, 184, 188, 192, 194, 347, 350, 365, 375
- infectious disease, viii, 5, 91, 92, 163, 165, 179, 188, 192, 194, 375
- infectious diseases, 5, 163, 188, 192, 194, 375
- inferences, 134, 137
- inflammation, 4, 25, 28, 48, 57, 65, 69, 79, 235, 348
- inflammatory, xii, 5, 29, 47, 50, 57, 170, 347, 348
- inflammatory bowel disease, 5
- inflammatory disease, 29
- inflammatory mediators, 57
- inflammatory response, 47
- inflammatory responses, 47
- influenza, 188, 192, 375, 376, 383
- influenza a, 383
- influenza vaccine, 375, 383
- information processing, 271
- information seeking, 393
- information sharing, 388
- informed consent, 171
- infrared, 325
- infrastructure, 23
- infusion model, 27
- infusions, 52
- ingestion, 93, 94, 164, 175, 179, 235
- inhalation, 93, 164, 165, 174, 175, 361, 362
- inheritance, 201, 269
- inherited, 260, 269
- inhibition, vii, 1, 3, 10, 26, 61, 115, 286
- inhibitor, 44, 170, 383
- inhibitors, 375
- initiation, 12, 15, 18, 38, 41, 171
- injection, x, 169, 170, 199, 239, 251, 252
- injuries, vii, ix, 38, 39, 47, 48, 147, 148, 149, 150, 151, 152, 153, 155, 156, 158, 159, 160, 161, 162, 171, 179, 185
- injury, ix, 20, 39, 47, 52, 54, 57, 68, 74, 79, 86, 89, 147, 149, 151, 152, 153, 154, 155, 156, 159, 160, 165, 170, 172, 213, 236, 391, 398
- innervation, x, 200, 237
- inoculation, 383
- inoculum, 373, 374, 375, 376
- inorganic, 108, 110
- inorganic filler, 108
- insects, 363
- insertion, 156, 325, 326, 328, 331
- insomnia, 177
- inspection, 213, 248, 403, 408
- inspiration, 142

instability, vii, 1, 5, 9, 285
 institutions, 180, 318
 instruction, 62
 instructors, 393
 instruments, 102, 105, 136, 138, 141, 164, 165, 175, 177, 178, 185, 187, 189, 194, 331, 335, 342, 405
 insurance, 119, 120, 122, 123, 125, 139, 140, 143, 169
 insurance companies, 125
 intangible, 127
 integration, 58, 129, 139, 288, 303
 integrity, 49, 104, 108
 intellectual disabilities, 287, 294
 intelligence, vii, x, 1, 2, 3, 6, 10, 24, 26, 27, 30, 32, 34, 267, 268, 269, 271, 277, 345
 intensive care unit, xiii, 291, 366, 372, 374, 380, 385
 intentionality, 6
 intentions, 14, 18, 23, 33
 interaction, 5, 22, 57, 389, 397
 interactions, xiii, 200, 233, 269, 387, 395, 397
 interdisciplinary, 49
 interface, 112, 303, 304, 337, 343, 354
 interference, 187, 200, 319
 interferon, 181
 interleukin, 25
 internal consistency, 29
 International Classification of Diseases, 161
 internet, 120
 interpersonal communication, 393, 399
 interpersonal relations, 32, 388
 interpersonal relationships, 388
 interpersonal skills, 390, 393, 399
 interstitial, 68, 169
 interval, 41, 171
 intervention, xiii, 2, 13, 22, 31, 36, 55, 61, 65, 69, 78, 120, 121, 123, 125, 127, 128, 130, 132, 133, 141, 155, 158, 159, 171, 176, 249, 371, 375, 376, 377, 378, 379
 interview, 397
 interviews, 169, 179, 393
 intracranial, 37, 177, 323
 intramuscular, 168
 intraoperative, 312, 314, 323, 331, 334
 intravascular, 50
 intravenous, 50, 52, 54, 62
 intrinsic, xiii, 13, 164, 223, 387
 intuition, 6
 invasive, xi, 5, 39, 58, 63, 102, 164, 174, 178, 189, 295, 306, 312, 316, 328, 337, 364, 368, 390, 397
 investigations, 225

investment, vii, 1, 2, 9, 26, 318
 iodine, 376, 377, 378, 379
 ionic, 60, 97
 ionizing radiation, 318
 ionomer, 101, 105
 ions, 105
 Iran, 267
 iritis, 56
 iron, 361
 irradiation, 36, 40, 41, 53, 59, 68, 71, 74, 78, 81, 83, 84, 86
 irrigation, 56, 74, 248, 350, 352, 354
 irritable bowel syndrome, 5
 irritation, 51, 54, 58, 156
 ischemia, 292
 ischemic, 291
 ischemic stroke, 291
 Islamic, 267
 isolation, 2, 102, 109, 115, 174, 361, 363
 Israel, 303, 312, 344
 Italy, 91, 147, 148, 163, 166, 169, 171, 179, 181, 182, 183, 184, 185, 194, 368
 IVC, 37

J

JAMA, 145, 181, 381, 397
 Japan, 371, 377
 Japanese, 384
 jaw, x, 40, 43, 65, 70, 72, 153, 161, 275, 281, 282, 283, 285, 286, 287, 291, 292, 293, 297, 298, 299, 307, 317, 319, 320, 324, 325, 327, 336, 348
 Jerusalem, 303
 jobs, 270
 joint pain, 407
 joints, 65, 282
 Jordan, 222, 262
 judgment, 8, 21, 22, 27, 41, 120, 121, 122, 123, 125, 128, 140, 141, 268
 Jun, vi, 195, 280, 347, 397, 398
 justice, 33

K

Kaiser Family Foundation, 396
 kappa, 47
 kappa B, 47
 keratinocytes, 354
 kidney, 16, 166, 172

kinetics, 115

Korean, 262

L

laceration, 149, 153

lack of confidence, 4

lactic acid, 118

Lactobacillus, 71

language, 62, 138, 188, 277, 278

large-scale, 167

laryngoscopy, 149, 155

larynx, 35, 76, 81, 284, 286, 365, 367

laser, 115, 311, 325, 326, 337, 350, 352, 354, 356

law, 134, 186, 190

leadership, 125

leakage, 74, 100

learning, 13, 31, 268, 270, 273, 274, 276, 277

learning process, 276

LED, 303

Legionella, 175, 176, 182, 184, 186, 187, 191, 193, 196, 197

Legionella pneumophila, 176, 184, 197

Legionella spp., 175, 176, 186, 187, 191, 193, 196

leisure, 11

lesions, viii, xii, 36, 40, 41, 42, 44, 46, 49, 57, 69, 91, 92, 94, 95, 101, 104, 114, 115, 128, 165, 209, 213, 217, 218, 221, 249, 349, 350, 351, 352, 355, 357, 359, 361, 365, 403

lethargy, 8

leukemia, 49, 59, 80, 84, 363, 364, 365, 366, 368, 369

leukemic, 72

leukocyte, 170

levator, 293

levodopa, 375

life satisfaction, 7

lifestyle, 23, 288

life-threatening, 48, 128, 332

lifetime, 3, 36, 40, 44, 71, 73, 96, 172

ligament, 73, 152, 155, 157, 162, 407

light emitting diode, 303

likelihood, 12, 19, 21, 22, 92, 128, 153, 391

limitation, 63, 158

limitations, viii, 8, 12, 13, 48, 53, 55, 77, 91, 106, 121, 124, 125, 127, 131, 144, 296, 316, 319, 323, 327, 401, 408

linear, 7, 272, 273, 274, 275, 277, 315, 317, 325

linear function, 274

linear regression, 7

lingual, 65, 67, 100, 296, 317, 360, 369, 408

linkage, 315

links, 107

lipopolysaccharide, 57

liquids, 56, 61, 189, 281, 286, 359

litigation, 140

liver, 168, 172, 362, 372, 381

liver abscess, 381

liver disease, 362

livestock, 33

local anesthesia, x, 169, 199, 218, 221, 236, 239, 246, 252

local anesthetic, 166, 221, 239

localization, xii, 303, 315, 357, 358, 361, 363, 364, 367

locus, 6, 394, 399

logical deduction, 268

London, 114, 143, 144, 149, 160

long period, 58, 65, 105, 362

longevity, 20, 96, 101, 102

longitudinal studies, 348

longitudinal study, 111, 353

long-term impact, 72

long-term retention, 157

Los Angeles, 117

losses, 57, 349

love, 8

low-income, 24

low-level, 9, 376

LPS, 57

lubrication, 55, 60, 64

lung, 20, 282, 374, 382

lung cancer, 20

lung disease, 382

lungs, 281, 361, 365

lymph, 36, 37

lymph node, 36, 37

lymphocyte, 5

lymphoma, 59

lysis, 66

M

M1, 37, 84

machines, 187, 268, 279, 309, 311, 315

mad cow disease, 177

magnetic, 319, 320

magnetic field, 319

- maintenance, 12, 15, 18, 21, 40, 43, 48, 49, 56, 58, 62, 65, 68, 73, 75, 83, 86, 101, 109, 113, 193, 235, 236, 258, 350, 354, 355
- major depression, 7
- maladaptive, 8, 13, 287
- malaise, 54
- males, 201, 227, 360
- malignancy, 84
- malignant, 5, 33, 77, 80, 87, 360
- malignant melanoma, 5, 33
- malnutrition, 38, 61, 62, 66, 373
- malocclusion, 68, 148, 149, 285, 286
- malpractice, 389, 390, 398
- management, ix, 10, 19, 33, 36, 38, 44, 49, 50, 55, 62, 70, 73, 75, 77, 78, 79, 84, 86, 87, 88, 110, 114, 139, 144, 147, 148, 155, 156, 158, 162, 169, 180, 184, 194, 209, 213, 282, 291, 318, 332, 352, 353, 358, 368, 369, 375, 381, 382, 389, 393, 399
- mandates, 131, 387
- mandible, xi, 36, 49, 54, 64, 66, 67, 69, 81, 82, 87, 88, 149, 151, 153, 222, 281, 282, 283, 285, 286, 287, 288, 289, 290, 292, 297, 298, 299, 302, 309, 321, 324, 326, 327, 328, 329, 330, 331, 332, 350, 408
- mandibular, 65, 69, 72, 74, 76, 78, 87, 128, 153, 154, 200, 221, 222, 251, 252, 253, 254, 274, 282, 283, 286, 287, 289, 292, 293, 298, 317, 320, 322, 327, 353, 367, 401, 408
- mango, 51
- manipulation, 54, 93, 107, 194, 395
- manners, 201, 202
- mannitol, 377
- manufacturer, 103
- mapping, 312
- marijuana, 30
- market, 97, 100, 108, 110
- Markov, 130, 141, 146
- Markov model, 130
- marrow, 59, 78, 80, 84, 85, 363
- Marx, 69, 70, 78, 87, 88
- mask, 174
- Massachusetts, 345
- masseter, 285, 286, 292, 293
- mastery, 388
- mastication, 54, 60, 93, 102, 287, 288, 290, 292, 293, 294
- masticatory, 40, 63, 100, 222, 287, 289, 290, 292, 293, 294, 407
- masticatory muscle activity, 292
- materials science, 128
- matrix, 47, 93, 99, 107, 110, 122, 201, 297, 337, 338, 339, 340, 341
- matrix metalloproteinase, 99
- maxilla, 67, 149, 151, 201, 222, 223, 237, 238, 255, 256, 297, 301, 308, 309, 320, 321, 325, 327, 328, 330, 344
- maxillary, xi, 76, 89, 92, 128, 148, 152, 153, 154, 200, 221, 222, 223, 224, 225, 226, 230, 231, 232, 233, 234, 235, 250, 251, 253, 254, 255, 256, 258, 260, 262, 264, 265, 293, 297, 298, 318, 325, 326, 327, 333, 334, 335, 336, 341, 345, 349, 365, 401, 402, 404, 405, 408
- maxillary sinus, 297, 298, 334, 335, 349, 365, 401, 405
- maxillofacial area, vii, 127, 326
- MCL, 405
- meals, 44, 49, 61, 217, 288
- meanings, 4
- measles, 180
- measurement, xi, 40, 79, 131, 291, 295, 300, 317, 324, 333, 335, 336, 389, 397
- measures, vii, 8, 9, 10, 14, 27, 33, 35, 38, 44, 58, 62, 119, 136, 141, 148, 163, 167, 169, 173, 178, 180, 185, 188, 312, 317, 358, 374, 375, 380, 392, 395, 396
- meat, 33, 56, 290
- mechanical properties, 100
- media, 19, 124, 157, 270, 377, 394
- median, 171, 205, 206, 208, 290, 360, 373
- mediators, 57
- medical care, 24, 389
- medical school, 392
- medical student, 6, 10
- medication, 83, 133, 373
- medications, 36, 50, 57, 58, 92, 373
- medicine, xiii, 80, 119, 120, 122, 123, 130, 131, 134, 144, 145, 387, 390, 392, 393, 394, 395, 396
- MEDLINE, 93
- melanoma, 5, 33, 36
- melon, 51
- membranes, 35, 57, 165, 178, 196, 351, 372
- memory, 22, 270
- men, 3, 7, 153
- meningitis, 362, 366
- meningoencephalitis, 362
- mental health, 4, 24
- mental model, 140
- mental processes, 10
- mercury, 93, 94, 111
- mesenchyme, 200, 233

- meta analysis, 263
meta-analysis, 85, 118, 130, 131, 135, 136, 137, 138, 139, 383, 399
metabolic, 222, 390, 397
metagenomics, 372
metalloproteinases, 99
metals, 108
metamorphosis, 122
metastasis, 36, 37
methyl methacrylate, 107
metropolitan area, 182
Mexico, 366, 367
Mexico City, 366
microbes, 48, 372, 375, 377
microbial, ix, 49, 165, 166, 173, 176, 184, 185, 186, 187, 192, 193, 194, 196, 282, 349, 377, 381
microbiota, 213, 235, 349, 353
microflora, 44, 57, 89, 101, 371, 372, 374, 375, 377, 378, 379, 380, 382
microorganism, 165, 166, 361, 362, 363, 364
microorganisms, 45, 48, 57, 71, 84, 164, 165, 169, 173, 175, 180, 184, 191, 193, 194, 358, 360, 363, 364, 365
microscope, 322
microscopy, 361
microspheres, 351
microvascular, 334
microwave, 187
migration, 201, 351
milk, 50, 56, 94, 157, 210, 211
mimicking, 367
mineralization, 233
mineralized, 98
mining, 130
minority, 92
misconception, 132
misinterpretation, 132, 316
misleading, 64
mixing, 99, 107, 186
MMA, 111
MMPs, 99
mobility, 40, 41, 42, 65, 78, 155, 156, 157, 211, 216, 288, 407
modalities, 36, 39, 46, 118, 119, 140
modality, xii, 40, 63, 315, 317, 347, 348, 350
modeling, 130, 334
models, vii, xi, 1, 2, 11, 12, 15, 17, 19, 23, 26, 120, 140, 197, 295, 321, 327, 328, 335, 352, 387, 389, 393, 397
moderates, 24
moderators, 31
modern society, 121
modulation, 81, 285, 370
moisture, 55, 95, 101, 104, 109, 372
molecules, 172, 233
monkeys, 353, 355
monomer, 107
monomers, 98, 107, 112
mood, 1, 3, 7, 8, 26, 28, 32
morbidity, 2, 5, 28, 38, 61, 172, 373, 380
morning, 186
morphine, 50
morphogenesis, 232, 265
morphological, 116, 201, 221, 234, 364
morphology, viii, 91, 92, 100, 113, 301, 364, 369, 404, 405
mortality, 2, 5, 28, 36, 75, 172, 368, 373, 375, 380, 383, 387
mortality rate, 172, 375
mothers, 209, 261
motion, 282, 315, 335, 339, 340, 344
motivation, 4, 7, 10, 13, 19, 29, 31, 40, 140, 209
motives, vii, 1, 2, 9, 10
mouth, ix, xii, 4, 10, 35, 39, 40, 44, 46, 48, 49, 50, 51, 53, 54, 56, 57, 58, 59, 63, 64, 65, 68, 71, 72, 83, 84, 105, 128, 147, 149, 153, 154, 157, 170, 174, 184, 196, 214, 286, 314, 317, 318, 319, 332, 350, 354, 357, 360, 363, 372, 373, 375, 376, 377, 379, 380
mouthguard use, ix, 147, 148, 153, 159, 161
movement, viii, xi, 40, 61, 65, 108, 118, 123, 132, 137, 157, 236, 281, 285, 287, 293, 309, 339, 342
mucormycosis, 363, 365, 366, 368, 369
mucosa, ix, xii, 39, 41, 43, 44, 46, 47, 48, 49, 50, 51, 52, 54, 58, 60, 64, 68, 80, 94, 147, 148, 149, 155, 212, 214, 216, 307, 311, 330, 348, 357, 358, 359, 361, 364, 365
mucous membrane, xiii, 35, 165, 178, 371
mucous membranes, 35, 165, 178
multidimensional, 9
multidisciplinary, 49, 124, 139
multiple factors, 68
multiple myeloma, 36
multiplication, 361
multiplicity, 35
muscle, 63, 65, 230, 283, 285, 286, 292, 293, 407
muscle contraction, 283, 286, 293
muscle force, 285
muscle relaxant, 65
muscle spasms, 407

muscles, 40, 61, 63, 64, 65, 283, 284, 285, 286, 287, 292, 293
 music, 395
 mutation, 265
 mutations, 174, 233
 mutuality, 388
 myasthenia gravis, 361
 mycelium, 358, 361
 mycobacterium, 164, 173, 174, 175, 184
 myeloid, 365
 myeloma, 36
 myocardial infarction, 25

N

nanocrystalline, 351, 355
 narcissism, vii, 1
 narcotic, 66
 nasal cavity, 37, 224, 225, 334, 365
 nasopharyngeal carcinoma, 37, 40, 75, 76, 81, 83, 88, 89
 nasopharynx, 36, 37, 52, 80
 nation, 1, 124
 National Institutes of Health, 121, 142
 native population, 151
 natural, 55, 59, 95, 170, 172, 268, 351, 353, 355, 362, 363
 nausea, 54, 56
 navigation system, xi, 295, 303, 304, 305, 306, 307, 309, 312, 313, 314, 315, 318, 319, 321, 323, 325, 328, 331, 332, 334, 341, 344
 neck, vii, viii, 35, 36, 38, 39, 40, 46, 52, 60, 61, 62, 63, 71, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 128, 323, 326
 neck cancer, viii, 35, 38, 52, 60, 61, 62, 63, 75, 76, 77, 78, 79, 81, 82, 83, 84, 85, 86, 87, 326
 necrosis, 25, 47, 48, 52, 53, 66, 69, 87, 157, 365
 needles, 164, 166, 169, 178, 188, 192, 312
 negative consequences, 4, 74
 negative emotions, 2, 5
 negative outcomes, 20
 negative relation, 391
 neglect, 7
 neonatal, 211, 217, 260
 neoplasm, 373
 neovascularization, 70
 nerve, 36, 65, 296, 297, 298, 299, 335, 360
 nerve blocks, 65
 nerves, 36, 37

network, 7, 18, 107, 180, 233, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280
 neural crest, 200, 201
 neural network, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278
 neural networks, 268, 271, 276, 277
 neurodegenerative, x, 177, 281
 neurodegenerative disorders, 177
 neurological disorder, 282
 neurons, 271, 272, 277, 279
 neuropathy, 38, 72
 neurosurgery, 303, 312, 320, 323, 334, 345
 neurotic, 5
 neuroticism, 3
 neurotoxicity, 72, 73
 neutropenia, 38, 44, 46, 48, 49, 57
 neutrophils, 49
 New England, 381
 New World, 118
 New York, 27, 31, 76, 79, 80, 145, 362, 366
 New Zealand, 161
 Newton, 6, 30, 392, 398
 NHS, 196
 NIC, 79
 Nigeria, 117
 NIH, 121, 397
 NNT, 133, 143
 Nobel Prize, 119
 nodes, 36, 37, 141, 271, 272
 noise, 136, 315, 322
 non-clinical, 4
 non-invasive, 307, 309, 329
 non-smokers, 28
 normal, 30, 37, 38, 48, 54, 55, 60, 61, 82, 88, 154, 177, 222, 225, 227, 285, 290, 293, 382, 401
 norms, 15, 30, 122
 North America, 197, 324, 326, 327, 364
 Norway, 159
 nuclear, 47
 nurse, 5, 49, 398
 nurses, 166, 376, 380
 nursing, 31, 131, 291, 372, 373, 374, 375, 376, 377, 380, 381, 382, 383, 384
 nursing care, 384
 nursing home, 372, 373, 374, 375, 376, 377, 380, 381, 382, 383, 384
 nutrient, 186
 nutrients, 100, 372
 nutrition, 51, 60, 61, 294
 nutritional deficiencies, 360

nutritional disorders, 222

O

observational learning, 13
 observations, 119, 133, 354, 355
 obstruction, 40, 62, 332
 occluding, 411
 occlusion, xi, 97, 103, 128, 157, 281, 282, 283, 285, 288, 289, 300, 308, 315, 316, 359, 407, 408, 411
 occupational, 4, 8, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 176, 179, 181, 182, 184, 196, 288
 occupational health, 181
 odontogenic, 221, 232, 321, 405
 oils, 57
 old age, 184
 older adults, 26, 291, 383, 384
 older people, 287
 olfactory, 200
 omission, 317
 oncology, xi, 75, 79, 82, 83, 86, 333
 opacity, 231, 232, 233
 operating system, 337
 operator, 319, 411
 opiates, 50
 opioids, 50
 opportunist, 361
 opposition, 11
 optic nerve, 36
 optical, xi, 303, 304, 315, 319, 323, 324, 327, 331, 333, 335, 337, 338
 optimal health, 139
 optimism, 3, 7, 20, 27, 34
 optimization, xi, 271, 333, 335, 336
 optoelectronic, 331
 oral antibiotics, 74
 oral cavity, vii, xiii, 35, 36, 44, 48, 49, 52, 54, 55, 57, 59, 71, 73, 79, 80, 82, 87, 118, 127, 177, 178, 179, 214, 223, 249, 265, 282, 307, 358, 362, 364, 365, 371, 384
 oral health, vii, xiii, 1, 2, 4, 8, 9, 11, 17, 23, 26, 27, 29, 32, 33, 38, 39, 44, 55, 73, 77, 80, 119, 137, 139, 161, 181, 182, 196, 209, 213, 235, 261, 266, 288, 290, 291, 292, 293, 294, 350, 369, 371, 372, 373, 375, 376, 377, 378, 380, 381, 384
 oral health problems, 293, 294
 oral hygiene, x, xiii, 3, 7, 25, 28, 29, 32, 34, 38, 39, 40, 41, 42, 43, 44, 45, 48, 49, 50, 51, 56, 58, 62, 65, 68, 71, 73, 75, 92, 109, 119, 200, 213, 214,

217, 234, 235, 236, 249, 281, 282, 288, 349, 358, 361, 371, 373, 374, 375, 376, 377, 380, 384
 oral surgeon, 197, 296, 314, 319
 organ, 38, 76, 77, 363
 organic, 102, 105, 107, 358
 organic matter, 358
 organism, 176
 orientation, xi, 23, 27, 33, 296, 303, 319, 333, 335, 336, 339, 340, 391, 394, 401
 orofacial disharmonies, x, 267
 oropharynx, 36, 37, 38, 54, 79, 80, 82, 87, 373
 osteoblasts, 66
 osteocytes, 66
 osteomyelitis, 78, 351, 353, 372
 osteoporosis, 4, 15, 29
 osteotomies, 318, 324
 osteotomy, xii, 334, 344, 348
 otolaryngologist, 225
 outcome of interest, 131
 outpatient, ix, 184, 397
 outsourcing, 319
 overlay, xiii, 407
 oversight, 124
 oxygen, 69, 70, 88, 372, 374

P

packaging, 99
 pain, x, 4, 5, 8, 9, 10, 27, 38, 40, 44, 46, 48, 49, 50, 51, 54, 61, 63, 64, 65, 66, 72, 73, 74, 79, 80, 89, 144, 146, 155, 157, 199, 239, 287, 322, 348, 390, 391, 393, 398, 399, 402, 407
 pain management, 50, 144, 399
 palate, x, 35, 39, 42, 44, 46, 49, 61, 199, 200, 201, 206, 207, 208, 209, 211, 212, 214, 221, 222, 223, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 237, 238, 239, 248, 249, 252, 256, 257, 260, 261, 262, 263, 264, 265, 266, 297, 359, 360, 363, 365
 palliative, 48, 55, 63
 pancreatic, 56
 panic disorder, 3
 papillomavirus, 76
 paracoccidioidomycosis, 365
 parainfluenza, 164, 173
 parallel processing, 277
 parameter, 273, 275
 parasites, 359
 parasymphathetic, 56
 parental attitudes, 263

-
- parental criticism, 9
 parenteral, ix, 163, 167, 178
 parents, x, 92, 199, 213, 214, 217, 223, 235, 236, 249, 266, 288
 Paris, 118
 Parkinson, 282, 291
 Parkinson's disease, 282
 parotid, 52, 53, 54, 81, 82, 362, 367
 parotid gland, 53, 54, 81, 362
 parotitis, 180
 particles, 50, 51, 93, 107, 108, 110, 174, 175, 193, 194, 281, 362
 partnerships, 124, 388
 passive, xi, 4, 169, 186, 193, 196, 283, 295, 303, 305, 316, 318, 319, 388, 394
 pathogenesis, xii, 26, 32, 69, 79, 84, 232, 357, 366, 383
 pathogenic, xii, 75, 164, 165, 175, 180, 197, 347, 348, 349, 351, 361, 372, 380
 pathogens, ix, x, xii, 59, 71, 163, 164, 173, 176, 179, 180, 181, 194, 281, 282, 349, 357, 362, 373, 374, 375, 376, 378, 379, 380, 382, 383, 384
 pathologist, 62
 pathology, xii, 65, 118, 119, 175, 200, 202, 347, 348, 352, 353, 369, 381, 401, 407
 pathophysiological, 291
 pathophysiology, 86, 87
 pathways, 120, 141
 patient care, 50, 387
 patient-centered, 140, 387, 388, 393, 394, 395
 PCA, 50
 PCR, 167, 168, 169, 176
 pectin, 50
 pedal, 187
 pediatric, 110, 111, 113, 145, 161, 213, 249, 368, 369
 pediatric patients, 368
 peer, 23
 peers, 8
 pellicle, 102
 peptide, 351
 peptides, 351
 perceived control, 20
 perceived norms, 15
 perceived self-efficacy, 17
 perception, 4, 7, 12, 13, 15, 18, 19, 60, 82, 131, 166, 181, 390, 391
 perceptions, 8, 9, 10, 12, 15, 19, 20, 21, 33, 34, 195, 389, 391, 398
 perfectionism, vii, 1, 9, 26, 27, 32
 perforation, 62, 365, 367, 408
 periodic, 62, 188
 periodontal, ix, 3, 6, 7, 23, 26, 27, 28, 29, 30, 33, 34, 38, 39, 40, 41, 42, 57, 59, 62, 73, 78, 85, 89, 118, 147, 148, 151, 152, 155, 157, 162, 235, 261, 282, 285, 292, 348, 349, 350, 351, 352, 354, 372, 374, 381, 382, 407
 periodontal disease, 3, 6, 26, 27, 28, 29, 30, 33, 34, 39, 40, 41, 42, 59, 73, 85, 118, 151, 235, 292, 372, 374, 381, 382
 periodontitis, 24, 25, 28, 29, 30, 32, 34, 42, 43, 57, 62, 349, 350, 353, 354, 383
 periodontium, 5, 73, 155
 peripheral arterial disease, 24
 peritonsillar abscess, 65
 permeability, 98
 permit, 2, 18, 23, 96, 131, 138
 peroxide, 51, 107, 189, 352
 perseverance, 4
 personal communication, 380
 personal control, 20
 personal hygiene, 178
 personal relations, 388
 personal relationship, 388
 personal values, 394
 personality, vii, 1, 2, 3, 4, 5, 13, 24, 25, 27, 30, 31, 32, 34, 393, 398
 personality characteristics, vii, 1, 2, 393
 personality traits, 4, 34
 persuasion, 13, 14
 perturbation, 5
 pessimism, 5
 petroleum, 57
 pH, 51, 57, 60
 pharmacological, 169, 171, 172, 173, 180, 375
 pharyngeal, 377, 382, 384
 pharyngeal flora, xiii, 372
 pharynx, 35, 53, 286, 287, 374
 phenol, 189
 phenotype, 230
 phenytoin, 265
 Philadelphia, 23, 81
 phone, 91, 148, 185
 phosphate, 56, 71, 84, 97, 98, 105, 350, 351
 photographs, 75
 photoinitiated, 101
 PHS, 28
 physical activity, 11
 physical properties, 105, 106, 108
 physicians, xiii, 387, 388, 389, 392, 395, 396

- physicians, 397
physico-chemical properties, viii, 91
physiological, 31, 165, 209, 358, 389
physiology, 6, 81, 119
physiotherapy, 65
pilot study, 27, 84, 292, 320, 324, 325, 330, 332, 354, 365, 377, 383
pipelines, 175
placebo, 80, 83, 84, 354, 385, 393
planar, 298
planning, viii, x, xi, 5, 40, 41, 42, 91, 123, 213, 251, 267, 273, 274, 280, 295, 296, 300, 301, 302, 303, 315, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 329, 330, 333, 334, 335, 336, 337, 341, 342, 344, 358, 401
plants, 363
plaque, 3, 4, 6, 25, 28, 29, 34, 40, 41, 42, 44, 45, 49, 50, 51, 56, 62, 71, 72, 73, 75, 100, 102, 118, 213, 234, 235, 236, 282, 350, 354, 355, 372, 373, 374, 375, 377, 382, 383, 385
plaques, 359, 360
plasma, 94, 111, 166, 168, 169, 170, 173, 351
plasma levels, 170
plastic, 210, 213, 218, 255, 256, 352
plastic surgeon, 255
plastic surgery, 213
platelet, 62, 63, 351
platelet count, 62
platelets, 49
play, ix, 3, 6, 22, 57, 108, 121, 148, 152, 159, 173, 177, 179, 183, 184, 201, 373, 388
plug-in, 337
PMS, 303
pneumonia, xi, xiii, 38, 61, 176, 281, 282, 287, 288, 291, 292, 371, 372, 373, 374, 375, 376, 380, 381, 382, 383, 384, 385
polarity, 132
polyethylene, 154, 189, 193
polymer, 107, 108, 114
polymer chains, 108
polymer matrix, 107
polymerase, 168, 367
polymerase chain reaction, 168, 367
polymerization, 98, 101, 105, 107, 108, 109, 115, 116, 311
polymerization process, 107, 311
polymers, 110, 116
polysaccharide, 361, 375, 383
poor, xiii, 7, 36, 38, 39, 40, 43, 44, 55, 58, 66, 68, 70, 71, 74, 92, 94, 95, 97, 102, 109, 119, 133, 149, 211, 243, 256, 287, 296, 316, 358, 360, 371, 373, 374, 390, 391
population, viii, 20, 23, 24, 26, 28, 36, 50, 77, 89, 91, 92, 94, 103, 115, 131, 133, 137, 151, 160, 166, 168, 169, 173, 174, 175, 176, 209, 223, 263, 265, 291, 292, 382, 383, 405
population group, 209
pores, 187
porous, 58, 355
ports, 148, 149
positive attitudes, 30
positive feedback, 292
positive relation, 391
positive relationship, 391
post traumatic stress disorder, 3
postoperative, xii, 61, 235, 333, 342, 380
posttraumatic stress, 24
posttraumatic stress disorder, 24
posture, 288, 289, 290
poverty, 27
powder, 105, 352
power, x, 4, 6, 107, 131, 133, 136, 267, 269, 277, 387, 396
powers, 359
practical knowledge, 180
predictability, 156, 296
prediction, 28, 33
predictors, vii, 1, 17, 24, 27, 81, 201, 287, 398
predisposing factors, 75, 358, 360, 361
pre-existing, 57
preference, 10, 71, 141, 388, 394, 396
pregnancy, 172
pregnant, 94, 359
pregnant women, 94
premature infant, 368
premenopausal, 24
premenopausal women, 24
preschool, 110, 234, 261
preschool children, 110, 261
pressure, 18, 155, 157, 187, 209, 248, 294, 309, 395
prevention, vii, ix, xi, xiii, 20, 22, 24, 38, 39, 40, 41, 43, 44, 48, 49, 50, 51, 52, 55, 57, 59, 65, 68, 70, 71, 73, 74, 77, 78, 79, 80, 83, 84, 85, 87, 102, 118, 119, 120, 124, 127, 144, 147, 148, 158, 159, 162, 177, 183, 185, 188, 192, 194, 195, 209, 211, 249, 281, 282, 288, 291, 353, 358, 371, 372, 374, 375, 376, 381, 382, 405
preventive, vii, 12, 13, 20, 21, 23, 31, 35, 38, 43, 44, 45, 49, 51, 62, 71, 73, 77, 80, 92, 101, 102, 103,

- 104, 105, 109, 114, 115, 116, 125, 148, 155, 158, 185, 213, 214, 233, 235, 380
- preventive programs, 235
- prices, 158
- primary care, 158, 159, 389
- primary school, 151
- primary teeth, viii, 43, 91, 92, 95, 96, 100, 103, 106, 109, 110, 115, 116, 155, 156, 161, 262
- primary tumor, 37, 61
- prions, 164, 177
- private, 9, 23, 27, 140, 144, 161, 185, 196, 197
- private practice, 144, 161, 197
- private sector, 140
- proactive, vii, 1
- probability, 11, 13, 14, 22, 42, 68, 130, 133, 136, 155, 165, 235
- probability judgment, 22
- probe, 306, 307, 312, 316, 337, 338, 342
- problem solving, 24
- problem-focused coping, 6
- production, 39, 47, 52, 55, 57, 82, 184, 193, 201, 283, 285, 291, 310, 319, 331, 332, 359, 368
- professions, 23
- prognosis, ix, 25, 36, 40, 41, 42, 45, 74, 147, 148, 157, 158, 353, 395
- program, 44, 45, 65, 92, 122, 321, 322, 393, 399
- proinflammatory, 291
- pro-inflammatory, 57
- proliferation, 70, 184, 233, 351
- property, iv, 269, 270, 272, 278
- prophylactic, ix, 44, 45, 51, 58, 73, 163, 173, 180
- prophylaxis, 41, 42, 43, 52, 59, 63, 79, 80, 84, 85, 144, 167, 168, 171, 172, 173, 180, 181, 182, 214, 217, 354, 355, 366
- proposition, 132, 133
- propulsion, 286, 288
- prostate, 368
- prostheses, xii, 39, 41, 43, 49, 51, 58, 60, 68, 73, 128, 154, 357
- prosthesis, 66, 296, 300, 317, 318, 327, 330, 345
- prosthetic device, viii, 117, 372
- prosthetics, 128
- prosthodontic dental care, viii, 117
- protection, ix, 9, 13, 19, 31, 54, 55, 147, 153, 154, 162, 174, 175, 178, 179, 180, 185, 188, 192, 193, 194, 318, 349
- protective role, 55, 201
- protein, 177, 182
- proteinase, 170
- proteins, 71, 200
- proteolytic enzyme, 359
- protocol, 49, 55, 69, 70, 73, 78, 80, 88, 129, 135, 136, 137, 173, 249, 320, 321, 349
- protocols, 49, 78, 80, 127, 132, 145, 202, 209, 235, 317, 318, 325, 329, 352
- prototype, 21
- protozoa, 175
- pseudo, 358, 365
- Pseudomonas*, xiii, 59, 164, 175, 176, 182, 184, 186, 371, 374, 377, 378, 380
- Pseudomonas aeruginosa*, 59, 175, 176, 182, 184, 186
- Pseudomonas spp.*, 164, 175, 176
- psychological processes, 19
- psychological states, 28
- psychological stress, 34
- psychological variables, 2, 23
- psychology, 12, 19, 23
- psychopathology, 34
- psychophysiology, 33
- psychosocial factors, 24, 30, 33
- psychosocial stress, 5, 30, 33
- psychoticism, 3
- ptyerygium, 262
- public health, ix, 23, 123, 144, 147, 148, 158, 159, 182, 200
- Public Health Service, 80
- public policy, 159
- public sector, 140
- pulp, ix, 41, 71, 72, 74, 95, 96, 105, 128, 147, 148, 150, 152, 155, 156, 157, 162, 177, 182, 243
- pumice, 102, 115
- punishment, 11
- PVAc, 154
- pyorrhea, 118

Q

- quality assurance, 184, 318
- quality control, 145
- quality of life, 8, 17, 25, 30, 32, 38, 54, 65, 76, 81, 82, 84, 288, 290, 376, 387
- Quality of life (QOL), 76, 79, 82, 86, 89, 345, 371, 372
- quartz, 107, 187
- questionnaire, ix, 184, 185, 193, 194, 294
- questionnaires, 50, 185, 187

R

- radiation, 36, 37, 38, 40, 41, 42, 43, 45, 46, 47, 48, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73, 74, 77, 78, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 92, 297, 318, 321, 322, 325, 328
- radiation damage, 52, 59, 68, 71
- radiation therapy, 37, 41, 46, 52, 53, 54, 60, 63, 68, 71, 74, 77, 78, 80, 81, 82, 83, 84, 87, 88, 89
- radiography, 189, 296, 318, 327, 328, 332
- radiological, 355
- radiopaque, 300, 320, 330
- radiotherapy, 36, 37, 39, 40, 41, 42, 44, 46, 48, 51, 52, 53, 54, 57, 58, 59, 60, 61, 63, 65, 66, 68, 71, 73, 74, 77, 78, 79, 81, 82, 83, 84, 86, 87, 88, 89, 329
- radius, 6
- radon, 15, 34
- random, 133, 136
- random errors, 136
- randomized controlled clinical trials, 70
- range, xii, 22, 46, 105, 108, 125, 130, 131, 158, 159, 169, 170, 187, 211, 213, 273, 276, 277, 297, 315, 317, 318, 334, 344, 387, 389, 390, 393
- raphe, 212
- rapid prototyping, xi, 295, 311, 312, 315, 319, 321, 323
- rash, 19, 54
- rating scale, 392
- ratings, 10, 390, 391, 392
- readership, 125
- real time, 340, 342
- reality, 121, 181, 324, 349
- reasoning, 10, 20, 268
- recall, 21, 38, 73, 92, 101, 103, 389
- receptors, 25, 55, 59
- reciprocity, 389
- recognition, 23, 89, 138, 168, 174, 337, 388, 390, 393
- reconstruction, xi, 38, 299, 300, 312, 326, 327, 333, 334, 335, 341
- reconstructive surgery, 69, 70
- record keeping, 402
- recovery, 12, 48, 53, 60, 73, 223, 395, 399
- recurrence, 36, 55, 73, 201, 231, 288, 352
- redness, 348
- reference frame, 301, 303, 305
- reference system, 307
- reflexes, 373
- refractory, 88
- regeneration, 356
- Registry, 166, 182
- regression, 7, 130, 212
- regular, x, 3, 7, 11, 28, 32, 39, 44, 50, 56, 62, 73, 124, 159, 179, 249, 281, 330, 393, 404
- regulation, vii, 1, 3, 8, 19, 26, 47, 120, 294
- regulations, 180
- regulators, 79
- rehabilitate, xi, 281
- rehabilitation, x, xi, 73, 128, 200, 281, 282, 288, 294, 296, 325, 330, 333, 334, 341, 345, 348
- reimbursement, 140
- reinforcement, 11, 18
- relationship, xiii, 3, 9, 12, 17, 24, 25, 26, 27, 28, 30, 33, 34, 82, 88, 92, 149, 154, 159, 176, 185, 193, 221, 243, 256, 285, 309, 335, 339, 382, 387, 389, 390, 391, 392, 397, 398, 399
- relationships, 8, 17, 22, 29, 86, 388, 389, 396
- relatives, 201
- relevance, 127, 130, 133, 134, 135
- reliability, 30, 138, 139, 142, 322, 334, 344
- remediation, 393
- remission, 74, 360
- remodeling, 68
- renal, 368
- renal failure, 368
- repair, 47, 68, 74, 106, 119, 144, 209, 218, 222, 234, 249, 254, 255, 256
- reparation, 94, 287
- replication, 66
- representativeness, 22
- representativeness heuristic, 22
- reptiles, 363
- research design, 126, 131, 135
- research funding, 23
- resection, xi, 36, 61, 69, 70, 328, 333, 335, 351
- reservation, 76, 77, 106
- reservoir, 57, 58, 165, 175, 282, 362, 374
- reservoirs, 105, 175, 176
- residential, 381
- resilience, vii, 1, 6, 7, 26, 307
- resin, 74, 92, 94, 97, 98, 99, 101, 102, 104, 105, 106, 107, 108, 109, 110, 112, 113, 114, 115, 116, 154, 156, 300, 309, 313, 314, 316, 408
- resins, 104, 114, 115, 192
- resistance, 74, 107, 108, 110, 173, 176, 358, 381
- resolution, 47, 123, 139, 303, 304, 315, 317, 326, 345, 351
- resources, 7, 17, 18, 22, 23, 77, 105

- respiration, 286
 respiratory, x, xiii, 164, 165, 173, 174, 175, 176, 178, 281, 282, 288, 291, 362, 372, 373, 374, 375, 376, 377, 378, 379, 380, 382, 383, 384
 restorations, viii, 41, 42, 68, 73, 91, 93, 94, 95, 96, 99, 101, 104, 105, 106, 108, 109, 110, 111, 113, 115, 116, 125, 128, 214, 249, 251, 252, 253, 326, 349, 409
 restorative dentistry, viii, 92, 100, 109, 110, 118, 132
 restorative materials, viii, 91, 92, 93, 94, 95, 106, 107, 108, 111, 115, 243
 retardation, 7
 retention, viii, 54, 57, 91, 92, 100, 101, 102, 103, 107, 113, 115, 154, 157, 258, 280, 407
 returns, 61
 rewards, 13
 Reynolds, 84
 rhinitis, 56
 rhinorrhea, 225
 rice, 214
 risk assessment, 92, 110, 322
 risk behaviors, 17, 20, 34
 risk factors, ix, 2, 24, 25, 36, 73, 104, 147, 148, 149, 160, 161, 163, 181, 234, 291, 373, 374, 375, 380, 382
 risk management, 19, 194
 risk perception, 19, 20, 34
 risks, 2, 5, 19, 20, 21, 23, 54, 74, 122, 127, 161, 178, 179, 185, 193, 223, 262, 344, 395
 risk-taking, 22, 141
 RNA, 168, 169, 170, 173, 181
 robotic, 322
 robotics, 331
 rods, 314
 Romania, 1, 26
 Rome, 166
 rotations, 315
 roughness, 354
 rubber, x, 40, 65, 94, 102, 111, 200, 209, 221, 236, 243, 252
 rugby, 149, 152, 161
 rural, 92
 saliva, 39, 40, 52, 53, 54, 55, 56, 57, 59, 60, 71, 72, 82, 86, 101, 102, 109, 164, 167, 169, 170, 173, 177, 178, 181, 184, 282, 287, 372, 373, 377, 383
 Salivary gland, 53, 54
 salivary glands, 35, 36, 52, 53, 54, 55, 71, 81, 84
 salt, 50, 56, 63, 105, 377
 salts, 189
 sample, 3, 4, 6, 8, 9, 10, 11, 33, 131, 133, 136, 191, 194, 195, 233, 277, 390, 391, 395
 sampling, 130, 131, 134, 138, 186, 191, 193, 196, 369
 Sartorius, 187
 SAS, 186, 191
 satellite, 303
 satisfaction, vii, 1, 7, 8, 135, 141, 388, 389, 390, 391, 394, 395, 397, 398
 scaling, 7, 8, 10, 42
 Scandinavia, 158
 scar tissue, 65, 222
 school, ix, 30, 124, 125, 133, 147, 148, 151, 152, 159, 160, 161, 182, 392, 395
 scientific knowledge, 180
 scientific method, 127, 132
 scores, 3, 5, 7, 8
 screening programs, 28
 SCT, xi, 295, 300
 scull, 328
 search, 34, 79, 125, 130, 138, 167, 168, 169, 214, 249, 362
 searching, 93
 Seattle, 280
 second generation, 97, 101
 secretion, 34, 53, 56, 71, 81, 83, 89
 secretory leukocyte proteinase inhibitor, 170
 security, 178
 sedative, 373
 sedative medication, 373
 seed, 214
 segmentation, 299, 325, 335, 336, 337
 selecting, 13, 14, 130
 self, 2, 3, 8, 10, 11, 14, 26, 28, 29, 33, 34, 98
 self-awareness, 6
 self-care, 28
 self-concept, vii, 1
 self-confidence, vii, 1, 18, 26
 self-consciousness, vii, 1, 9, 26, 27, 30
 self-control, vii, 1, 2, 11, 26
 self-efficacy, 3, 13, 14, 15, 17, 29
 self-esteem, vii, 1, 5, 8, 9, 17, 21, 26, 28, 32, 33, 391
 self-expression, 5

S

- sadness, 8
 safeguard, 163, 174, 177, 178
 safety, xi, 61, 83, 176, 186, 296, 318, 328, 333
 saline, 49, 51, 69, 74, 157, 176, 179, 214, 248, 352

- self-image, 21
self-monitoring, 11
self-presentation, 10
self-regulation, vii, 1, 8, 19
self-report, 5, 10, 24, 26, 392
self-reports, 392
SEM, 113, 356
semen, 170
sensation, vii, 1, 54, 56, 60, 71
sensation seeking, vii, 1
sensations, 5
sensing, 319
sensitivity, 51, 60, 86, 93, 95, 97, 100, 105, 130, 155, 156, 316, 345, 349, 384, 399
separation, 271
sepsis, 38, 46, 48, 57
septicemia, 75, 85
septum, 208, 209, 358
sequelae, 49, 59, 61, 77, 88, 222, 292
serology, 169, 175
serum, 52, 167, 168, 170, 362, 364
service provider, 392
services, iv, viii, ix, 21, 77, 118, 127, 131, 139, 140, 143, 152, 154, 158, 159, 184, 185, 195
SES, 2
severity, vii, 12, 13, 15, 25, 35, 36, 38, 44, 46, 48, 49, 52, 53, 56, 61, 62, 65, 70, 75, 79, 149, 151, 152, 153, 158, 160, 164, 176, 201, 221, 364
sex, 148, 185
sexual behaviour, 11
shade, 106
Shanghai, 333, 344
shape, 210, 225, 227, 236, 243, 360, 395, 407
shaping, 19
shares, 388
sharing, 388, 394
shear, 112
Shigella, 175
shock, 153, 154
short-term, 6, 18, 50, 101
shyness, vii, 1, 10, 26
siblings, 92, 230, 262
side effects, 36, 38, 46, 54, 56, 68, 86, 88, 394
sign, 155, 365, 375
signaling, 233
signalling, 265
signs, x, 40, 46, 75, 104, 118, 141, 174, 267, 351, 360, 361, 402
silane, 107
silica, 107, 110
silicate, 105, 108
silver, 92, 93, 94, 189
similarity, 22, 388
simulation, 335
sine, 134
sinus, 297, 298, 317, 334, 335, 349, 364, 365, 401, 404, 405
sinuses, 35, 37, 296, 363, 364
sinusitis, 73, 401
sites, xi, 25, 36, 60, 92, 103, 104, 323, 328, 329, 333, 334, 335, 358, 364, 410
Sjogren, 83, 84
skeletal muscle, 285, 286
skeleton, 65, 364
skills, 8, 10, 11, 122, 132, 159, 292, 296, 390, 392, 395, 399
skills training, 392
skin, 20, 66, 164, 165, 169, 170, 172, 174, 178, 179, 306, 337, 361, 363, 364, 365
skin cancer, 20
sleep, 7, 46, 52, 65, 128, 373, 375
sleep apnea, 128
sleep disturbance, 7
SLPI, 170
smiles, 391
smokers, 20, 28, 358
smoking, 2, 4, 11, 16, 20, 24, 28, 29, 30, 48, 51, 263, 349, 360, 361, 393
smoking cessation, 30, 393
smoothing, 156
soccer, 152
sociability, vii, 1, 10, 26
social anxiety, 10
social awareness, 10
social behavior, 23
social class, 149
social comparison, vii, 1, 10, 27, 33
social comparison theory, 10
social consequences, 12
social context, 10
social desirability, vii, 1, 10, 28, 31, 33
social evaluation, 9
social influence, 18
social influences, 18
social integration, 288
social isolation, 2
social network, 7
social norms, 15
social physique anxiety, vii, 1, 9
social psychology, 12

- social relations, 8
social relationships, 8
social resources, 17
social skills, 10
social status, 38
social support, 4, 17, 18, 31, 34
social support network, 18
socialization, 290
socioeconomic, 2, 92
socioeconomic status, 2, 92
socioemotional, 388, 392
socio-emotional, 392
socio-emotional, 396
sodium, 44, 51, 57, 71, 189, 201
soft palate, 39, 42, 46, 61, 208, 211
software, 129, 185, 268, 269, 271, 276, 280, 301, 303, 304, 309, 315, 317, 320, 336, 337, 341, 342, 343
soil, 174, 358, 362, 363
Solow, 300, 329
solubility, 105
solvents, 192
somatization, 28
sores, 51
South Africa, 151, 161
South American blastomycosis, 367
Southeast Asia, 36
spatial, 315, 335, 338, 339
species, 57, 71, 175, 197, 349, 358, 361, 362, 363, 364, 366, 367, 368, 372, 374, 377, 378, 379, 382, 384
specificity, 132
spectrum, vii, 28, 45, 263, 359, 361, 368
speech, 3, 37, 38, 54, 61, 62, 65, 86, 154
speed, 4, 175, 186, 193, 319, 402
spheres, 296
spices, 51
spinal cord, 36
spine, 345
splint, 157, 162, 293, 300, 327
splinting, 156, 157, 162
sponges, 50
sporadic, 177, 182, 362
spore, 189
sporotrichosis, 368
sports, ix, 147, 148, 149, 151, 152, 153, 154, 159, 160
SPSS, 185
squamous cell, 76, 78, 81, 87
squamous cell carcinoma, 76, 78, 87
St. Louis, 87
stability, xi, 106, 107, 130, 256, 281, 283, 284, 285, 286, 287, 288, 291, 292, 316, 317, 330, 331
stabilization, x, 15, 157, 281, 282, 283, 288, 300, 308, 345
stabilize, 157, 288
stabilizers, 110
stages, 7, 11, 14, 15, 33, 34, 36, 69, 70, 125, 213
stainless steel, 92, 95, 96, 106, 111
standard deviation, 133
standard error, 190, 355, 378, 379
standards, 9, 119, 128, 133, 136, 138, 140, 141, 178, 399
staphylococci, 377
Staphylococcus, xiii, 371, 373, 374, 377, 378
Staphylococcus aureus, 373, 374
statistical analysis, 136, 137, 138, 187, 320
statistics, 19, 75, 130, 133, 144, 185
status of children, 261, 263
steel, viii, 91, 92, 95, 96, 106, 111
stem cell transplantation, 55
stem cells, 351
stent, 31, 320, 321, 325
stereotypical, 21
sterile, 176, 187, 216, 377, 387
sterilization, 177, 178, 185, 187, 193
sternocleidomastoid, 63
sternum, 67
steroid, 353, 362
stimulus, 12
stock, 154
stoma, 128
stomatitis, xii, 54, 79, 80, 170, 357, 358, 359, 366, 368, 372
storage, 157, 162, 187
stoves, 185, 187
strain, 283
strains, 172, 361
strategies, ix, 6, 7, 13, 18, 21, 22, 23, 89, 123, 130, 139, 163, 169, 177, 178, 180, 282, 287, 316, 352, 374, 375, 376, 384
strength, viii, 15, 18, 91, 98, 99, 100, 101, 108, 110, 112, 113, 116, 122, 126, 127, 136, 144
streptococci, 45, 77, 374, 377
stress, vii, 1, 2, 3, 4, 5, 6, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 64, 108, 115, 156, 222, 391
stress factors, 4, 33
stressors, 5
stretching, 63, 65, 285
strictures, 61, 62

- stroke, 282, 291
 strontium, 105, 107, 108, 110
 students, 4, 6, 8, 9, 10, 11, 16, 24, 29, 123, 124, 125, 126, 132, 142, 159, 161, 166, 179, 196, 392, 399
 subjective, 4, 6, 8, 12, 16, 133, 141, 149, 151, 391, 392
 subjective well-being, 8
 subjectivity, 127
 subluxation, 149
 substance abuse, 4, 393
 substances, 68, 170, 360
 substitutes, 55
 substitution, 60
 success rate, 270, 348
 sucrose, 118
 suffering, xii, 21, 176, 357
 sugar, x, 40, 56, 71, 92, 118, 199, 211, 261
 sugar cane, 118
 suicidal, 7, 30
 sulfate, 50, 86
 supervision, 63, 148, 152, 154, 159
 supplements, 53, 60, 62
 supply, 67, 222, 317
 suppression, 374
 surface area, 285
 surface modification, 355
 surface roughness, 354
 surgeons, xi, 128, 164, 166, 178, 197, 296, 314, 333, 390
 surgeries, ix, 184, 194, 195, 209, 218, 249, 256
 surgery, vii, xi, xii, 35, 41, 42, 43, 55, 61, 63, 65, 66, 68, 70, 77, 81, 87, 88, 118, 163, 165, 169, 182, 186, 187, 188, 193, 213, 223, 249, 254, 260, 261, 262, 285, 292, 293, 295, 296, 303, 306, 309, 312, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 330, 331, 332, 334, 336, 342, 344, 345, 347, 348, 349, 350, 352, 354, 366, 380, 391, 393, 395, 398, 399
 surgical, ix, xi, 34, 36, 38, 41, 55, 61, 68, 69, 70, 73, 74, 83, 87, 127, 157, 163, 164, 169, 174, 175, 176, 177, 178, 179, 184, 188, 213, 222, 223, 225, 234, 249, 254, 255, 256, 264, 295, 296, 301, 303, 305, 306, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 339, 340, 341, 342, 343, 344, 345, 350, 351, 354, 368, 369, 390, 391
 surgical debridement, 70
 surgical intervention, 55, 61
 surgical pathology, 369
 surgical resection, 36, 61, 69
 surveillance, 166, 174, 175, 178, 181, 381
 survival, 36, 38, 76, 82, 85, 111, 157, 354, 382, 387
 survivors, 61, 82
 susceptibility, 12, 15, 20, 21, 36, 48, 54, 100, 102, 105, 166, 173, 201, 361, 368
 suture, 216, 247, 248, 256
 swallowing, x, 37, 39, 54, 55, 56, 61, 62, 65, 66, 71, 77, 86, 157, 213, 217, 252, 281, 282, 283, 286, 287, 288, 290, 291, 292, 373, 374, 375, 383
 Sweden, 113, 151, 159, 303, 311, 345
 swelling, 348, 393
 symbolic, 201
 symmetry, 286, 293
 symptom, 53, 73, 174, 270, 271, 278
 symptomatic treatment, 48
 symptoms, x, 3, 5, 7, 9, 12, 25, 31, 32, 33, 40, 49, 55, 66, 75, 118, 120, 122, 141, 194, 267, 269, 351, 390, 407
 syndrome, 5, 10, 83, 84, 282, 286, 288, 290, 291, 293, 294, 363, 369
 synthesis, 66, 137, 141, 145
 syphilis, 164

T

- tangible, 127
 tanks, 164
 target behavior, 11
 target population, viii, 118
 target populations, viii, 118
 task force, 123, 124
 taste, 53, 54, 57, 59, 60, 86, 350, 360
 taxonomy, 397
 TDI, 149, 151, 152, 155, 158, 159
 tea, 51, 118
 teachers, 159, 393
 teaching, 144, 181, 392, 395
 technician, 319
 technicians, 187
 temperament, 34
 temperate zone, 362
 temperature, 154
 temporal, 20, 285, 286, 293
 temporomandibular disorders, 73
 tension, 5, 234
 teratogen, 201
 teratogenic, 201
 teratogens, 201
 tetanus, 65, 188

-
- tetracycline, 352, 355, 356
 TGF, 200
 Thai, 78, 367
 Thailand, 35, 263, 365, 367
 Theory of Planned Behavior, 11, 15, 16, 25, 27
 therapy, xii, 8, 24, 31, 32, 34, 36, 37, 38, 39, 41, 44, 45, 46, 47, 48, 49, 52, 53, 54, 55, 56, 57, 59, 60, 62, 63, 65, 68, 70, 71, 73, 74, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 95, 96, 123, 145, 162, 170, 172, 184, 292, 347, 348, 349, 350, 351, 353, 354, 355, 356, 357, 359, 362, 395, 404
 thermoplastic, 154, 155
 thinking, 6, 22, 133, 144
 threat, 12, 13, 14, 20, 21, 22, 27, 71, 155
 threatened, 14
 threatening, 21, 38, 61, 62, 317
 threats, 14, 127
 three-dimensional, 52, 81, 107, 324, 327, 330, 334
 three-dimensional model, 327
 threshold, 94, 186, 187, 190, 191, 192, 193, 336
 threshold level, 190, 191, 192
 thresholds, 94
 throat, 54, 359
 thrombocytopenia, 49
 thrush, xii, 357, 359, 360
 thymoma, 361
 thyroid, 36
 time constraints, 158
 time periods, 118
 timing, 36, 353
 tin, 93
 tissue, ix, xii, 6, 36, 37, 38, 39, 41, 46, 47, 48, 49, 51, 53, 54, 55, 60, 65, 66, 68, 69, 70, 71, 72, 74, 86, 88, 89, 102, 112, 147, 148, 151, 153, 161, 177, 218, 219, 222, 234, 246, 255, 256, 296, 317, 334, 336, 347, 349, 352, 353, 354, 364, 372, 407
 titanium, 309, 310, 319, 341, 342, 349, 352, 355
 titration, 83
 TNF-alpha, 25
 tobacco, 36, 51, 68, 201, 360
 tolerance, 36, 54, 55, 68
 tongue, 360
 tooth transplant, 118
 toothbrushing, x, 3, 4, 7, 8, 11, 29, 32, 39, 44, 49, 50, 199, 213, 215, 217
 topical anesthetic, x, 50, 199, 239, 242, 251, 252
 topology, 271
 torque, 329
 toxic, 4, 38, 54, 77, 189, 192
 toxic effect, 38, 54, 77
 toxic products, 192
 toxicity, 36, 37, 38, 46, 52, 54, 57, 80, 93, 94
 toxins, 48
 trabeculae, 70
 tracheostomy, 128
 tracking, xi, 295, 303, 305, 306, 309, 315, 318, 324, 327, 331, 333, 334, 335, 337, 338, 339, 341, 342, 344
 traction, 153
 traditional model, viii, 117
 traffic, 19, 149
 trainees, 179
 training, ix, 23, 119, 120, 121, 122, 123, 128, 153, 159, 160, 166, 174, 179, 184, 249, 264, 271, 392, 395
 training programs, ix, 23, 184, 392, 395
 trait anxiety, 24
 traits, 4, 5, 34
 trajectory, 312, 334, 342
 transactions, 397
 transcription, 47, 200, 233
 transcription factor, 47, 200, 233
 transcription factors, 47, 200, 233
 transfer, 55, 83, 309, 312, 318, 322, 324, 330, 334, 410
 transformation, 187, 201, 306, 337, 338, 339, 359, 364
 transformation matrix, 337
 transforming growth factor, 230
 transition, 25, 146
 translation, 315, 337, 338
 translational, 122, 124, 141
 translocation, 57, 372
 transmission, 164, 165, 167, 169, 170, 171, 173, 174, 175, 176, 177, 178, 181, 182, 194, 195
 transplant, 57, 78, 85, 363, 368, 369
 transplant recipients, 78, 85
 transplantation, 46, 50, 55, 59, 80, 84, 118
 transport, 60, 157
 trauma, ix, 41, 48, 49, 51, 63, 65, 68, 75, 147, 148, 149, 151, 153, 155, 156, 158, 159, 160, 161, 162, 282, 362, 363, 405, 407
 traumatic incident, 156
 trees, 132, 141, 362
 trial, 50, 55, 76, 79, 80, 82, 84, 86, 114, 115, 131, 134, 355, 399
 tropical areas, 363
 trust, 6, 389, 394
 TTM, 12

tuberculosis, 164, 173, 174, 175, 181, 182, 184, 188, 189, 192, 365
 tumor, 36, 37, 38, 40, 41, 42, 45, 52, 54, 61, 318, 335
 tumor necrosis factor, 52
 tumors, 36, 38, 68, 83, 320
 tumour, 5, 25, 87, 88, 331, 361
 Turkey, 161
 turnover, 175
 twins, 201
 two-dimensional, 327, 401
 two-way, 387
 type 2 diabetes, 4, 354

U

ulcer, 47, 51, 66, 74, 390
 ulceration, 36, 51, 57, 59, 364
 ultraviolet (UV), 312, 314
 uncertainty, 33
 unconditioned, 112
 undergraduate, 8, 9, 10, 11, 125
 undergraduates, 32, 390
 uniform, 180, 407
 United Kingdom, 299
 United States, 3, 8, 33, 95, 110, 166, 167, 170, 171, 174, 176, 179, 180, 375
 updating, 114, 130
 upper airways, 359
 urethane, 107
 urinary, 56,
 urinary tract, 364
 urinary tract infection, 176
 urine, 94, 111
 user-defined, 335
 uvula, 208

V

vaccination, 24, 167, 168, 178, 188, 375, 383
 vaccinations, 180, 188, 192, 383
 vaccine, 167, 168, 179, 188, 375, 383
 vacuum, 308, 309, 320, 325, 329
 vaginitis, 359
 valence, 22
 validation, 33, 143, 294, 330
 validity, 30, 34, 127, 129, 138, 139, 142, 317
 values, 6, 8, 10, 11, 23, 98, 126, 130, 139, 141, 187, 189, 193, 270, 274, 275, 276, 278, 329, 330, 394

variability, 140
 variables, 2, 14, 15, 20, 21, 23, 33, 77, 86, 162, 165, 187, 195, 264, 269, 290, 388, 389, 395
 variance, 133
 variation, 60, 100, 151, 152, 158, 293, 315
 vascularization, 70
 vasoconstriction, 52
 vector, 338, 342, 362
 vegetables, 56
 vehicles, 71, 164, 173, 280
 vein, 132, 141, 170
 velocity, 287
 verbal persuasion, 13
 vessels, 70
 vibration, 156
 Victoria, 182
 videotape, 393
 violence, ix, 147, 148, 149, 152
 violent, 151, 153
 viral hepatitis, 165, 166, 167, 188, 192
 viral infection, 36, 59, 85
 virological, 172
 virulence, 165, 173, 364
 virus, 36, 59, 76, 85, 164, 165, 166, 169, 170, 173, 180, 181, 184, 195, 366, 367, 368, 369
 virus infection, 76, 85, 181
 viruses, 57, 164, 165, 173, 184
 viscosity, 107
 visible, 101, 103, 107, 108, 155, 401
 vision, 331
 visualization, 298, 300, 317, 335, 337, 342
 vitamin A, 361
 voice, 391
 voids, 103
 vomiting, 54
 vulnerability, 2, 13, 20, 23

W

Wales, 160
 wants and needs, 120
 warehousing, 187
 warfarin, 58, 85
 water, ix, 50, 51, 54, 55, 56, 63, 97, 103, 105, 119, 149, 154, 157, 164, 165, 175, 176, 178, 179, 181, 184, 185, 186, 187, 188, 189, 190, 192, 193, 194, 195, 196, 197, 214, 300, 350
 water quality, 181, 194
 water supplies, 164, 175, 176
 weakness, 389

wealth, 8, 140
 wear, 39, 54, 96, 107, 108, 110, 153, 154, 290, 294
 web, 182
 weight loss, 44, 54, 60, 65, 86, 174
 Weinberg, 331
 well-being, 1, 6, 8, 28, 29
 well-being therapy, 8
 wellness, 120, 144
 WHO classification, 149
 windows, 186
 wires, 154
 wisdom, 402
 withdrawal, 401
 WMD, 145
 women, 3, 7, 24, 30, 94, 153, 396
 Wong scale, 141
 Wong scales, 141
 work activity, 193
 work environment, ix, 184, 192
 workers, 181, 182, 193, 196, 375
 workstation, 303, 304
 World Health Organization (WHO), 46, 50, 80, 149, 150, 151, 158, 161, 263
 worldview, 396
 worms, 118
 worry, vii, 1, 8, 21, 24, 26, 32
 wound healing, 5, 39, 51, 351, 354
 wound infection, 354

X

xerostomia, 37, 52, 53, 54, 55, 56, 57, 59, 60, 61, 63, 65, 71, 73, 74, 83, 84

Y

yeast, 57, 58, 360, 364, 366
 yeasts, 358
 yield, 131
 yogurt, 51
 young adults, 4, 34, 114, 294
 young women, 30
 ytterbium, 108
 yttrium, 350

Z

zinc, 60, 86, 93, 105, 107, 108
 zinc sulfate, 86
 zirconium, 108
 zoonotic, 366
 zygoma, xi, 295, 318, 324, 330, 333, 334, 336, 341, 342, 343, 344
 zygomatic, 334, 344, 345
 zygomycosis, 362, 363